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CHAPTER 1: INTRODUCTION

1.1 Background

Modular channel is one of the drainage designs that involve module to be use in the design of the drainage system. As modular channel is being used in this design, the different data or information involving the flow resistance and flow attenuation will be obtained for further research purpose in the future. Module is one of the important features that were installed in this drainage design and thus this channel is being known as modular channel. Modular channel application is familiar in the storm water management for on-site detention (OSD), bio-remediation and filtration pond other than being applied in the drainage design to control the storm water discharge.

Application of modular channel or module is also familiar in the rainwater harvesting system scene to act as a water filter. Rainwater will be going through infiltration and filtration to collect and produce clean, colourless and odourless water to be use for various purposes. This implementation will help to reduce the water supply needed and become one of the water saving measures.

The efficiency of the water channel flow and the water distribution process will be affected significantly with the application of modular channel. So, this research will be focusing on the suitability of this modular channel design as conveyance system and the characteristics of the flow attenuation and flow resistance that were affected. This research will be focusing on the test run on the lab by using flume model.

1.2 Problem Statement

Increase of flash flood cases in urban cities and frequent changes in world's climate urge the need for the better urban sustainable drainage solutions to eliminate the risk of flash flood. As the flash flood issues in urban area is getting worst by year contradict to the improvement in technology system to improve human life standard, this research was conduct to improve the drainage system condition by applying the modular channel design .

A laboratory study has been conducted to analyze the effect of modular channel to the velocity and on the Manning's n coefficient in an open channel on the hydraulic roughness. These modular channel designs also are more sustainable in the aspects of managing the flow rates and compatible to the environmental scene attenuating flows and controlling the downstream discharges.

1.3 Objectives and Scope of Study

1.3.1 Objectives

In this study, this modular channel design is investigated with various slopes, arrangement and flow rates. These projects consist of one main objective that should be achieved at the end of the project which is:

1) To evaluate the performances of the modular channel in terms of flow resistance and flow attenuation.

At the end of this project, author should be able to achieve the main objectives to complete this project successfully.

1.3.2 Scope of study

This study is limited by examining the flow of water by using modular channel in Universiti Sains Malaysia (USM) Engineering Campus. There will be installation of a few rows of module in channel cross section and water will pass through the module. The different in flow resistance will be recorded at different point. This research will be conduct at Physical Modelling Laboratory of River Engineering and Urban Drainage Research Centre (REDAC) at University Sains Malaysia.Two type of meter will be used to record the data which is Current Meter & Acoustic Doppler Velocimeter (ADV).

CHAPTER 2: LITERATURE REVIEW/THEORY

2.1 Module

Module or modular tank is also known as modular channel and consist of many different designs which will provide different flow attenuation. Module will be acting as temporary storage to store excess water in the underground to control and manage surface water runoff. Flow resistance of water will also be affected by the application of module in the channel.

Modular channel application as subsurface conveyance has only been primarily applied in Bio-ecological Drainage System (BIOECODS) in Universiti Sains Malaysia (USM) Engineering Campus (Li et al., 2011; Zakaria et al., 2003; Ab. Ghani et al., 2004) and sustainable urban drainage system in Taiping Health Clinic that were completed in 2005 (Li et al., 2011; Ab. Ghani., 2008).

Both modules have different design that will provide different flow attenuation cause by the different roughness coefficient. Subsurface module use in BIOECODS dimension is 405 mm x 465 mm x 607 mm while dimension of subsurface module use in Taiping Health Clinic is 410 mm x 450 mm x 685 mm. This former design is deemed as unsuccessful as it cause localize water ponding as the flow of storm water is slower than the infiltration rate of storm water into modular tank.

Figure 1: Subsurface module in BIOECODS
(*Source by Li et al., 2011*)

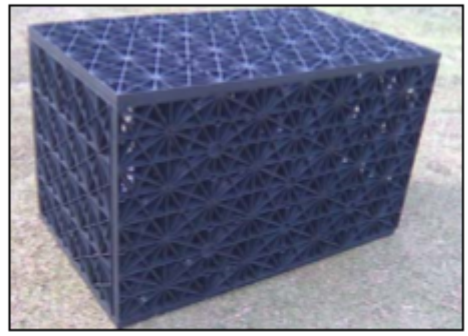
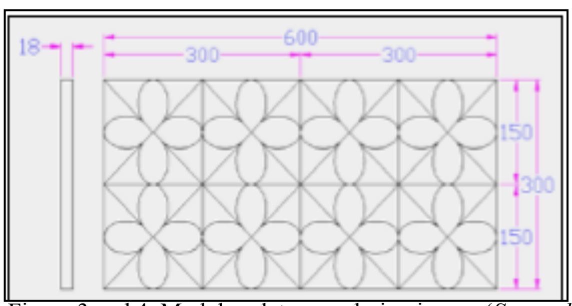


Figure 2: Subsurface module in Taiping Health Clinic
(*Source by Li et al., 2011)*

New design of module was proposed by *Li et al., 2011* to provide better flow attenuation with its larger surface opening. These design obtained the high correlation of 0.72 for equations developed by genetic programming.



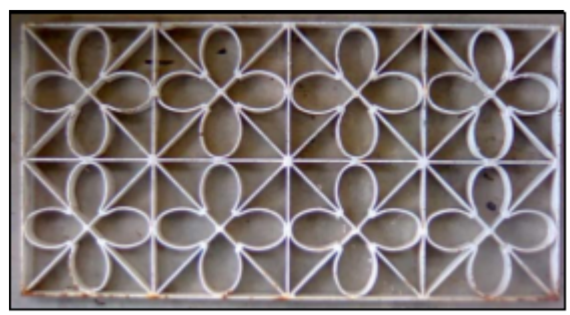


Figure 3 and 4: Modular plate new design in mm (*Source by Li et al., 2011*)

As for this research, latest design was installed in the flume and were used to collect the data by running numbers of experiments.

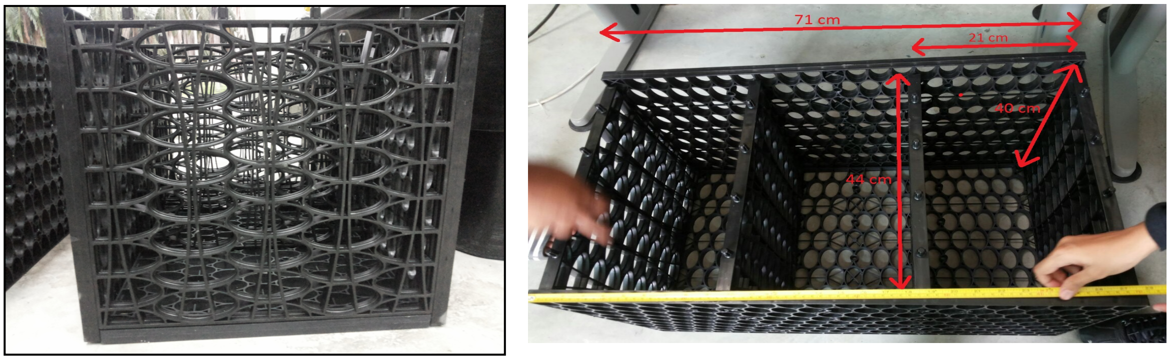


Figure 5: Modular plate design use in this research (440 mm x 400 mm x 210 mm per one section)

For future research, new latest design has arrived and no experiments are yet to be conducted with this module. The material of this module is different to the current material use for the module use in this research.

Figure 6: New latest modular plate design

As for current research, new setting of module in the flume will be applied to obtain the flow resistance through the modular channel and the performances of its flow attenuation.

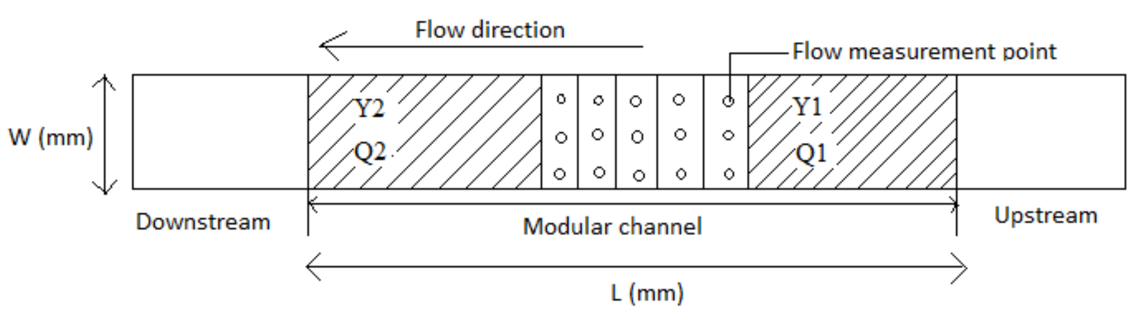


Figure 7: Modular channel cross-section

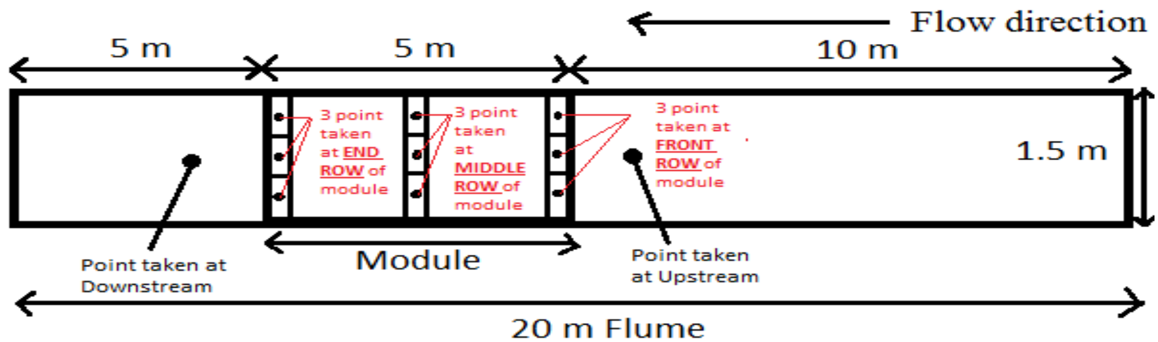


Figure 8: Flume dimension (actual)

As shown in the Figure 7 above, there will be two measure that will be examine in these research which is the flow rate, Q and water level, Y. Q_1 is the flow rate at the upstream of the channel while Q_2 is the flow rate at the downstream of the channel. Same case as flow rate, Y_1 is the level of water at the upstream of the channel while Y_2 is the level of water at downstream of the channel.

Measurement of velocity will be taken at $0.2y$, $0.6y$ and $0.8y$ of the flow measurement point where y is the flow depth from the water surface for water depth greater than 25 cm. The average velocity and average depth will be calculated from these data. The width, w and the length, L of the channel also are the important measurement that was recorded. The module will be located in a few rows across the channel.

2.2 Flow attenuation

Attenuation is the act where the chamber is functioning as temporary storage of surface water with suitable chamber below ground level. As for this research, the chamber that will be use is module. Module that was used needs to be in an appropriate size to accommodate the total runoff during rainfall peak periods. The stored water in module will then be released gradually in controlled manner into the downstream which will significantly reduce the risk of flood to occur.

Attenuation is included in the conservation of mass equation that is used to define the movement of water through a reach in HEC-RAS.From the HEC-RAS Hydraulic Reference Manual (Page 2-22), "Conservation of mass for a control volume states that the net rate of flow into the volume be equal to the rate of change of storage inside the volume." In other words, change in storage over time equal to inflow minus outflow. The equation is:

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = 0 \qquad \text{Equation (1)}$$

where A = flow area, Q = discharge, t = time, and x = length.

The discretion form of this is more practical to use and may be more familiar:

$$I - O = \frac{\Delta S}{\Delta t} \qquad \text{Equation (2)}$$

Where I = Inflow to a discrete control volume, O = Outflow, ΔS = Change in Storage, Δt = time duration

Attenuation is important to reduce the runoff rate of storm water and different components have been applied in the previous research such as ecological swale, on-line underground storage and dry pond. These components not only provide flow attenuation but also contribute to the treatment of storm water. A.Ainan et al. (2003) stated that the catchment response time to rainfall is about 40 minutes giving an indication that the component of ecological swale has a capability to delay the flow to the downstream.

Dry ponds show the relationship between Annual Recurrence Interval (ARI) and the emptying time by its retention behaviour. Dry ponds perform very well in retention of the storm water runoff for a typical duration before draining into the storm water system, therefore avoidance the occurrence of inundation at downstream end (A.Ainan et al., 2003).

Example of Flow attenuation table (1):

Rain Event (2016)	Rainfall Intensity (mm/hr)	ARI	Location Channel	Peak flow (l/s)		Volume (m^3)		Percentage Reduction (%)	
				(Inlet)	(Outlet)	(Inlet)	(Outlet)	Peak Flow	Volume
			Surface						
			Subsurface						
			Surface						
			Subsurface						
			Surface						
			Subsurface						
			Surface						
			Subsurface						
			Surface						
			Surface						
			Surface						
			Subsurface						
			Surface						

Figure 9: Table of flow attenuation

Example of Inflow and Outflow Hydrograph:

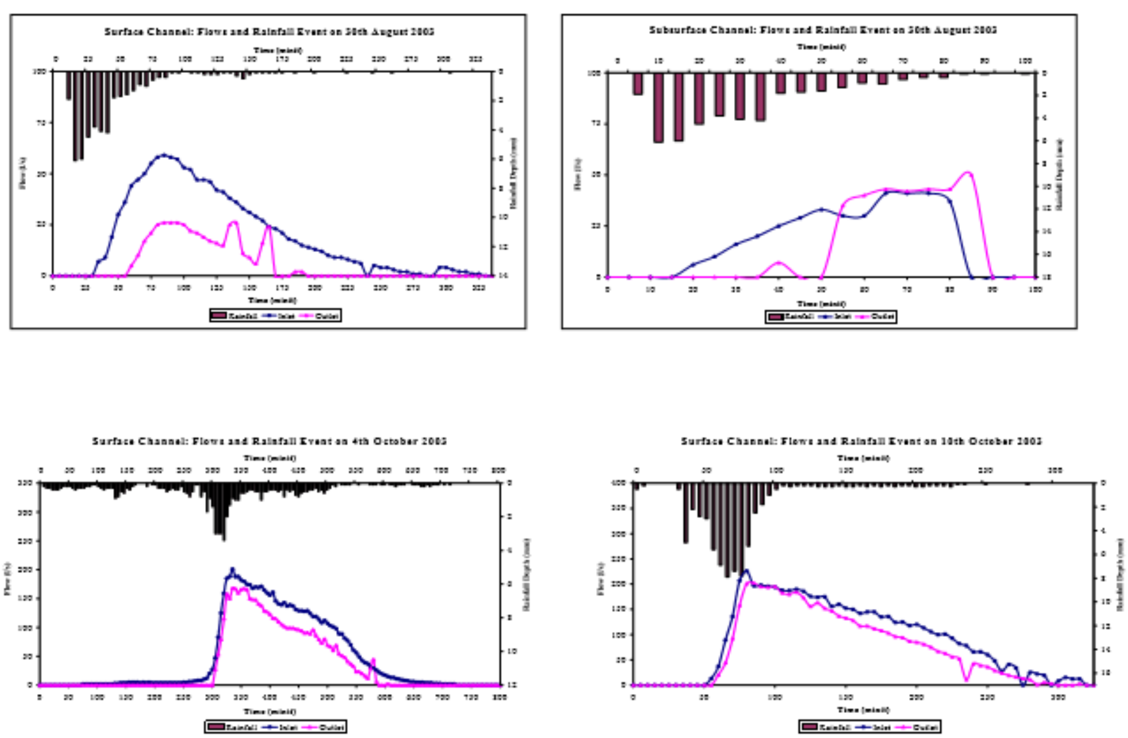


Figure 10: Example of Inflow and Outflow Hydrograph

2.3 Manning's n equation

Analysis of laboratory results can be done by Manning formula in metric form where the formula is:

$$\boxed{Q = VA = \frac{1}{n} A R^{\frac{2}{3}} S^{\frac{1}{2}},} \longrightarrow \text{Equation (3)}$$

Where Q is flow rate in $\frac{m^3}{s}$,

V is velocity in $\frac{m}{s}$,

A is Flow area in m^2,

n is Manning's roughness coefficient,

R is hydraulic radius in m,

S is Channel Slope in m

Manning's n formula can be derived from Equation (3) which is:

$$\boxed{n = \frac{1}{V} R^{\frac{2}{3}} S^{\frac{1}{2}}} \longrightarrow \text{Equation (4)}$$

A summary of ranges for Manning's n under different slope conditions will be recorded. Other than that, dimensionless analysis will be done to obtain an equation by governing the Manning's n formula. Manning formula in Equation (4) can be modified by switching the coefficient of 1.486 (English unit) or 1 (SI unit) by $\sqrt{g}$ (*Li et al., 2011; Yen, 1992*) so that the equation will be:

$$\boxed{V = \frac{\sqrt{g}}{n_g} R^{\frac{2}{3}} S^{\frac{1}{2}}} \longrightarrow \text{Equation (5)}$$

Li et al., (2011) and Searson (2009) stated that analysis of genetic programming was done by using GPTIPS which is a genetic programming tool for the use in MATLAB. Coefficient of determination (R^2) and root mean square error (RMSE) will be use to evaluate the performance of observed and predicted Manning's n models.

$$\boxed{R^2 = \left[\frac{\sum_{i=1}^{N} \left(O_i - \overline{O}\right)\left(P_i - \overline{P}\right)}{\sqrt{\sum_{i=1}^{N} \left(O_i - \overline{O}\right)^2 \sum_{i=1}^{N} \left(P_i - \overline{P}\right)^2}} \right]^2} \longrightarrow \text{Equation (6)}$$

$$\boxed{RMSE = \sqrt{\frac{\sum_{i=1}^{N} \left(O_i - P_i\right)^2}{N}}} \longrightarrow \text{Equation (7)}$$

Where O_i is observed values,

$\overline{O}$ is the mean of O_i,

P_i is predicted values,

$\overline{P}$ is the mean of P_i and

N is number of samples.

The model with R^2 value near to 1 is usually considered as the most suitable model for describing the observed data, and the model with smallest total uncertainty will have smallest RMSE. The target of this research is to evaluate the performance of module with respect to the R^2 value and RMSE.

Example of table for Manning's n for modular channel with different slope:

Manning's n	Module A		
	1:1000	1:750	1:500
Maximum			
Minimum			
Average			

Figure 11: Example of table for Manning's n for modular channel with different slope

Example of table for regression analysis in predicting roughness parameter $n_g / R^{\frac{1}{6}}$ for modular channel:

Modular Channel	Relationship	Coefficient of Determination, R^2	Root Mean Square Error, RMSE
Module A	$\frac{n_g}{R^{1/6}} = 0.479\left(\frac{B}{Y}\right)^{0.279}(S)^{0.391}$	0.816	0.005

Figure 12: Example of table for regression analysis in predicting roughness parameter $n_g / R^{\frac{1}{6}}$ *for modular channel*

Example of table for genetic programming in predicting roughness parameter $n_g / R^{\frac{1}{6}}$ for modular channel:

Type of Modular Channel	Relationship	Coefficient of Determination, R^2	Root Mean Square Error, RMSE
Module A	$\frac{n_g}{R^{1/6}} = 19.18S + 6.801\times10^{-5}\left(\frac{B}{Y}\right)^2 + 0.0345$	0.958	0.005

Figure 13: Example of table for genetic programming in predicting roughness parameter $n_g / R^{\frac{1}{6}}$ *for modular channel*

CHAPTER 3: METHODOLOGY/PROJECT WORK

3.1 Method of study

Experimental approach will be done by adopting the field open-channel to determine the hydrodynamics relation to modular channel. The final results will be finalized in the final report. The flow of the method of study that will be done is shown in the diagram below:

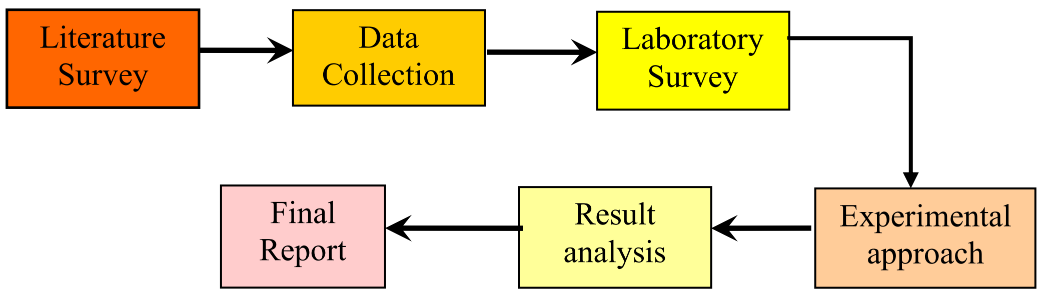


Figure 14: Flow chart of Method of Study

3.2 Research Methodology

Flume experiment will be conducted at Physical Modelling Laboratory of River Engineering and Urban Drainage Research Centre (REDAC) at University Sains Malaysia. The flume has dimension of length, width and height of a x b x c respectively. Subsequently, the flow rate, Q will be recorded at the upstream and downstream. Measurement of velocity will be taken at $0.2y$, $0.6y$ and $0.8y$ of the flow measurement point where y is the flow depth from the water surface for only depth of water greater than 25 cm. The average velocity and average depth will be calculated from these data.

3.2.1 Flow Chart of Research Methodology

a) Without Module

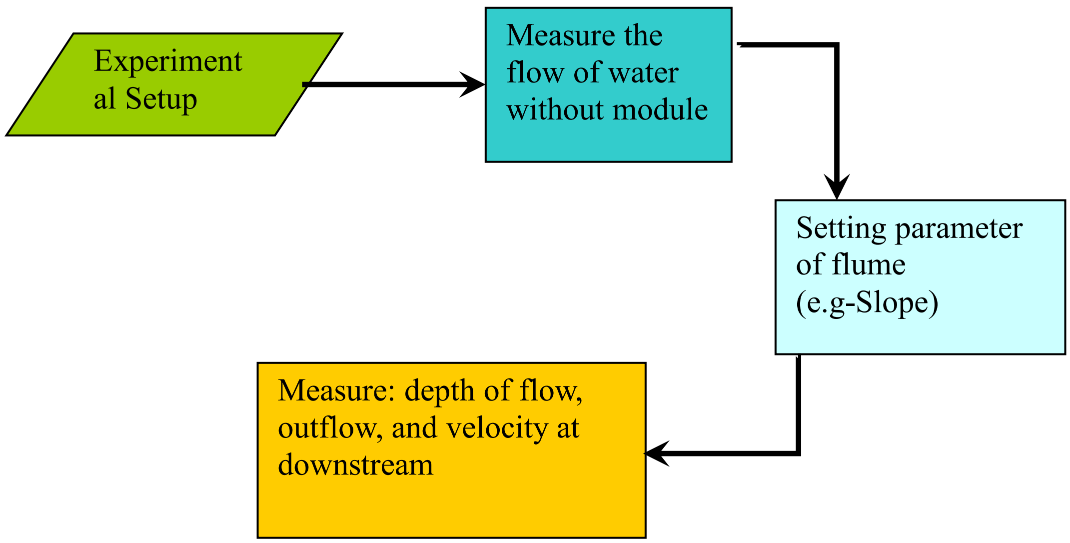


Figure 15: Flow Chart of Research Methodology without Module

b) With module

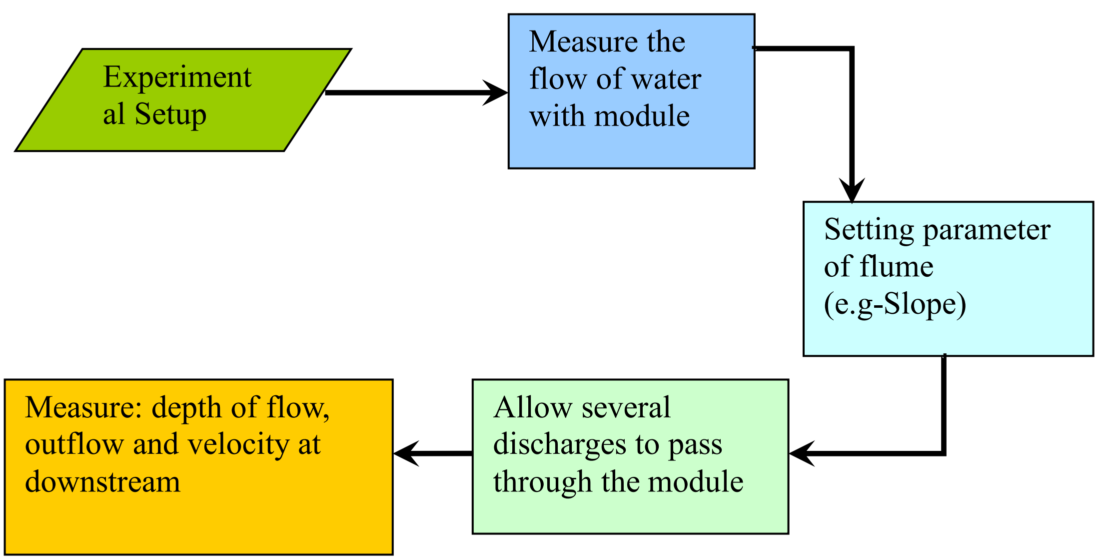


Figure 16: Flow Chart of Research Methodology with Module

3.2.2 Experimental procedure

1) The flume experiment will be set up in the laboratory with few rows of module in the channel (*Number of row may varied to obtain varied result of flow resistance and flow attenuation*)

2) Firstly, measure the flow of water in the channel with the installation of module.

3) Set the flume with the slope of 1:500 and 1:1000.

4) Allow different discharge of water to pass through the channel.

5) Measure the velocity of the water at different flow depth which is $0.2y$, $0.6y$ and $0.8y$ of the flow measurement point where y is the flow depth from the water surface for water depth more than 25 cm.

6) Calculate the average velocity of water from the result obtained in Step 5.

7) Measure the water flow at the upstream and downstream.

8) Repeat the experiment from Step 1 to Step 7 without the installation of module.

3.3 Key Project Milestone

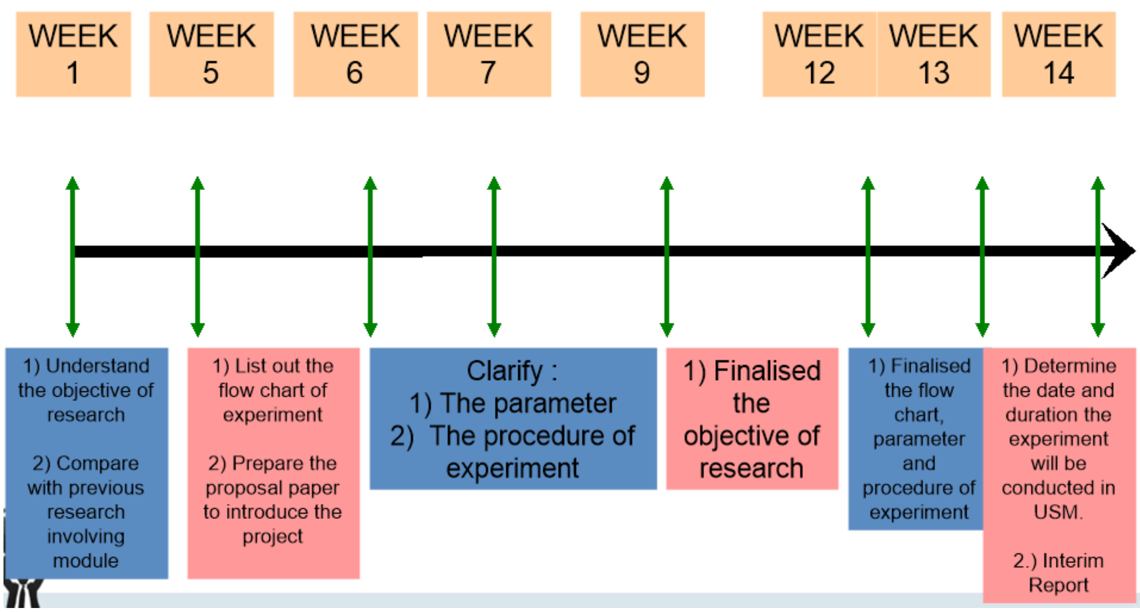


Figure 17: Key Project Milestone (FYPI)

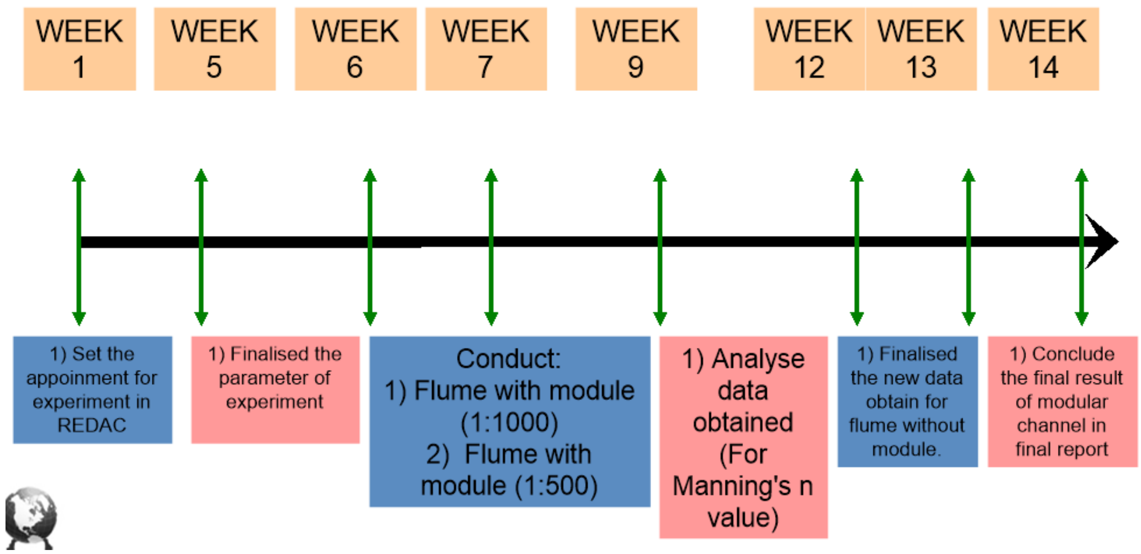


Figure 18: Key Project Milestone (FYPII)

3.4 Project Timeline

Gantt chart (*Final Year Project 1*)

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.	Selection of Project Topic	■	■												
2.	Preliminary Research Work		■	■	■	■									
3.	Submission of Extended Proposal								■						
4.	Proposal Defence										■				
5.	Project Work											■	■	■	
6.	Submission of Interim draft Report													■	
7.	Submission of Interim Report														■

∴ ■ Process

Figure 19: Gantt chart (Final Year Project 1)

Gantt chart (*Final Year Project 2*)

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.	Project work														
2.	Submission of Progress Report														
3.	Project work														
4.	Pre-SEDEX														
5.	Submission of Draft Final Report														
6.	Submission of Project Dissertation (Soft bound)														
7.	Submission of Technical Paper														
8.	Viva														
9.	Submission of Project Dissertation (Hardbound)														

Process Target Milestone

Figure 20: Gantt chart (Final Year Project 2)

CHAPTER 4: RESULT AND DISCUSSION

For Final Year Project 1 (FYP1), the lab experimental had not yet been conducted. The lab experiment will be conducted at Physical Modelling Laboratory of River Engineering and Urban Drainage Research Centre (REDAC) at University Sains Malaysia for two days. The lab experiment is done in Week 7 of Final Year Project 2 (FYP2).

Dimension of Flume (used in the Laboratory):

Height of flume: 1.0 m

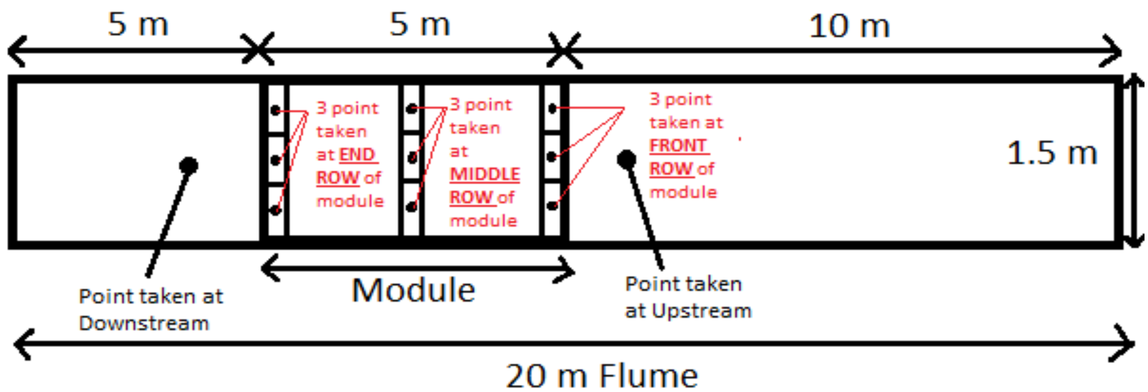


Figure 21: Flume dimension in Laboratory

Dimension of Module (used in the Laboratory):

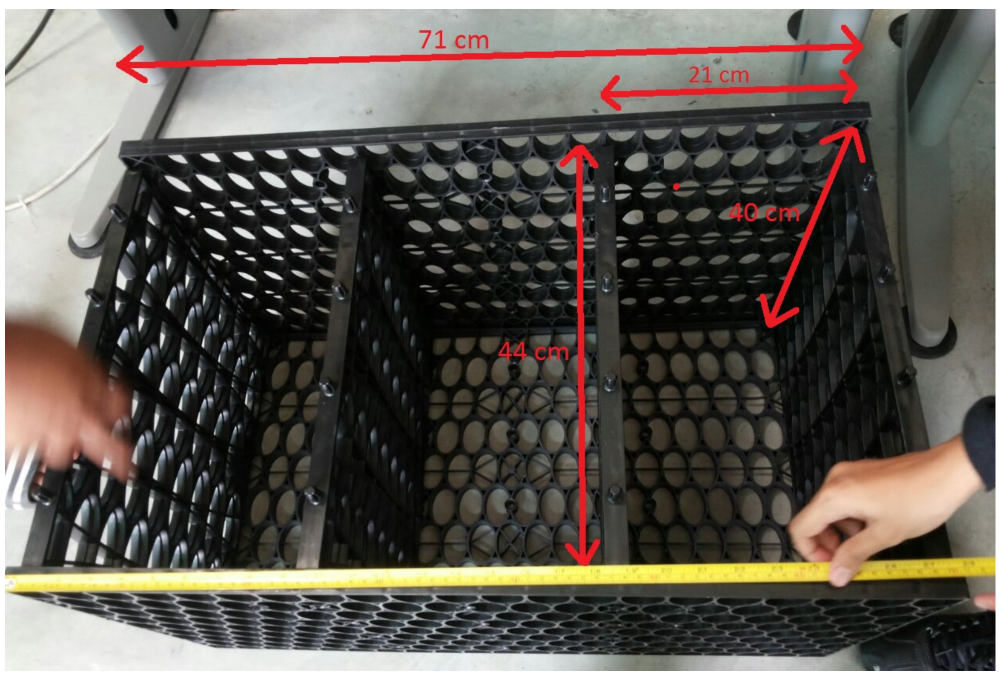


Figure 22: Module dimension in Laboratory

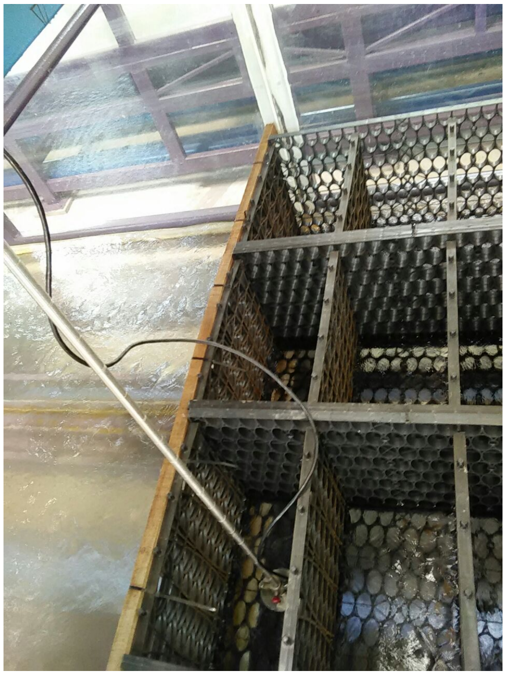


Figure 23: Taking the velocity reading in module

Figure 24: Reading the data from Velocimeter

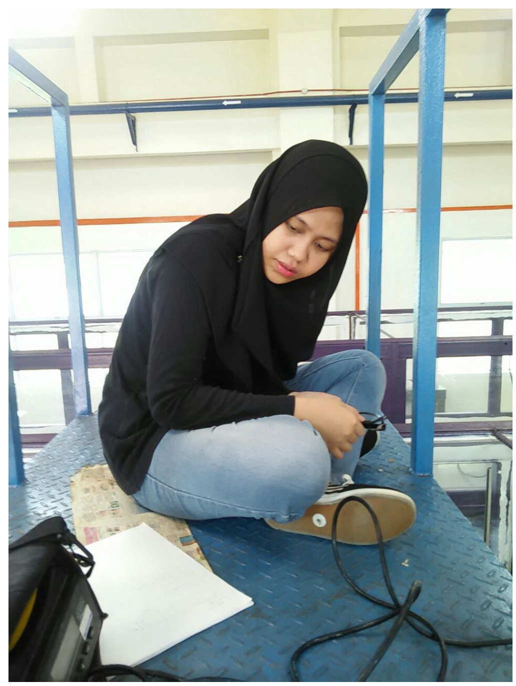


Figure 25: Slope controller

Figure 26: Reading the data from Velocimeter

Figure 27: Natural vegetated channel around USM Campus

4.0 Result

4.1 Without Module (using Acoustic Doppler Velocimeter, ADV)

For data of flume without module, this data is taken for two types which is Gate Partial Opening (GPO) and Gate Fully Opening (GFO) for each slope of 1/1000 and 1/500.

4.1.1 Slope 1:1000 (Gate Partial Opening, GPO)

Data generated for duration of 1 hour (2.39 pm to 3.39 pm):

	A	B	C	D	E	F	G
1	Date Time	Level (cm)	Velocity (m/s)	Flow (L/s)	Temperature (°C)	Conductivity ()	Power Supply(V)
2	27/1/2016 2:39 PM	17.44	0.07	19.41	33.09	99.93	13.09
3	27/1/2016 2:44 PM	22.64	0.1	33.3	33.02	99.94	13.08
4	27/1/2016 2:49 PM	23.68	0.05	16	32.89	99.94	13.08
5	27/1/2016 2:54 PM	22.19	0.04	13.81	32.76	99.92	13.06
6	27/1/2016 2:59 PM	18.77	0.05	15.24	32.70	99.93	13.07
7	27/1/2016 3:04 PM	18.03	0	0	32.63	99.93	13.08
8	27/1/2016 3:09 PM	19.78	0	0	32.57	99.93	13.07
9	27/1/2016 3:14 PM	21.81	0.08	24.99	32.57	99.94	13.08
10	27/1/2016 3:19 PM	22.83	0.06	21.93	32.50	99.94	13.08
11	27/1/2016 3:24 PM	23.33	0.06	19.86	32.50	99.94	13.06
12	27/1/2016 3:29 PM	23.55	0.07	24.23	32.50	99.95	13.08
13	27/1/2016 3:34 PM	23.84	0.06	20.73	32.50	99.92	13.05
14	27/1/2016 3:39 PM	40.25	0	0	32.50	99.93	13.04

Table 1: Data of level, flow & velocity for slope 1:1000 (GPO)

Slope	Y (cm)	Y (m)	V (m/s)	V (m/s)	Q (l/s)	Q (m3/s)	A, (m.sq)	Pw, (m)	R, (m)	n
0.001	17.44	0.17	0.07	0.07	19.41	0.019	0.262	1.849	0.141	0.123
0.001	22.64	0.23	0.10	0.10	33.30	0.033	0.340	1.953	0.174	0.099
0.001	23.68	0.24	0.05	0.05	16.00	0.016	0.355	1.974	0.180	0.202
0.001	22.19	0.22	0.04	0.04	13.81	0.014	0.333	1.944	0.171	0.244
0.001	18.77	0.19	0.05	0.05	15.24	0.015	0.282	1.875	0.150	0.179
0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#DIV/0!
0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#DIV/0!
0.001	21.81	0.22	0.08	0.08	24.99	0.025	0.327	1.936	0.169	0.121
0.001	22.83	0.23	0.06	0.06	21.93	0.022	0.342	1.957	0.175	0.165
0.001	23.33	0.23	0.06	0.06	19.86	0.020	0.350	1.967	0.178	0.167
0.001	23.55	0.24	0.07	0.07	24.23	0.024	0.353	1.971	0.179	0.144
0.001	23.84	0.24	0.06	0.06	20.73	0.021	0.358	1.977	0.181	0.169
0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#DIV/0!

Table 2: Data of R, Pw & Manning's n for slope 1:1000 (GPO)

4.1.2 Slope 1:1000 (Gate Fully Opening, GFO)

Data generated for duration of 1 hour (3.22 pm to 4.22 pm):

	A	B	C	D	E	F	G
1	Date Time	Level (cm)	Velocity (m/s)	Flow (L/s)	Temperature (°C)	Conductivity ()	Power Supply(V)
2	2/2/2016 3:22 PM	6.27	0.24	22.52	32.44	99.93	15.08
3	2/2/2016 3:27 PM	6.8	0.38	38.86	32.44	99.95	15.08
4	2/2/2016 3:32 PM	6.53	0.36	35	32.44	99.97	15.08
5	2/2/2016 3:37 PM	6.51	0.33	32.58	32.50	99.92	15.08
6	2/2/2016 3:42 PM	5.93	0.27	24.44	32.50	99.94	15.09
7	2/2/2016 3:47 PM	6.82	0.36	36.81	32.50	99.95	15.08
8	2/2/2016 3:52 PM	7.14	0.35	38.02	32.50	99.90	15.08
9	2/2/2016 3:57 PM	7.09	0.38	40.21	32.50	99.94	15.08
10	2/2/2016 4:02 PM	7.19	0.37	39.9	32.50	99.93	15.07
11	2/2/2016 4:12 PM	4.11	0.13	7.78	32.50	99.97	15.07
12	2/2/2016 4:17 PM	6.61	0.33	32.81	32.50	99.95	15.08
13	2/2/2016 4:22 PM	6.61	0.32	31.57	32.57	99.96	15.08

Table 3: Data of level, flow & velocity for slope 1:1000 (GFO)

Slope	Y (cm)	Y (m)	V (m/s)	V (m/s)	Q (l/s)	Q (m3/s)	A, (m.sq)	Pw, (m)	R, (m)	n
0.001	6.27	0.06	0.24	0.24	22.52	0.023	0.094	1.625	0.058	0.020
0.001	6.80	0.07	0.38	0.38	38.86	0.039	0.102	1.636	0.062	0.013
0.001	6.53	0.07	0.36	0.36	35.00	0.035	0.098	1.631	0.060	0.013
0.001	6.51	0.07	0.33	0.33	32.58	0.033	0.098	1.630	0.060	0.015
0.001	5.93	0.06	0.27	0.27	24.44	0.024	0.089	1.619	0.055	0.017
0.001	6.82	0.07	0.36	0.36	36.81	0.037	0.102	1.636	0.063	0.014
0.001	7.14	0.07	0.35	0.35	38.02	0.038	0.107	1.643	0.065	0.015
0.001	7.09	0.07	0.38	0.38	40.21	0.040	0.106	1.642	0.065	0.013
0.001	7.19	0.07	0.37	0.37	39.90	0.040	0.108	1.644	0.066	0.014
0.001	4.11	0.04	0.13	0.13	7.78	0.008	0.062	1.582	0.039	0.028
0.001	6.61	0.07	0.33	0.33	32.81	0.033	0.099	1.632	0.061	0.015
0.001	6.61	0.07	0.32	0.32	31.57	0.032	0.099	1.632	0.061	0.015

Table 4: Data of R, Pw & Manning's n for slope 1:1000 (GFO)

4.1.3 Slope 1:500 (Gate Partial Opening, GPO)

Data generated for duration of 1 hour (10.25 am to 11.25 am):

	A	B	C	D	E	F	G
1	Date Time	Level (cm)	Velocity (m/s)	Flow (L/s)	Temperature (°C)	Conductivity ()	Power Supply(V)
2	2/2/2016 10:25 AM	19.17	0.16	45	31.79	99.94	12.93
3	2/2/2016 10:30 AM	22.65	0.15	50.71	31.85	99.93	12.89
4	2/2/2016 10:35 AM	21.64	0.13	41.3	31.85	99.94	12.90
5	2/2/2016 10:40 AM	19.96	0.16	47.72	31.85	99.93	12.88
6	2/2/2016 10:45 AM	19.46	00.14	42.11	31.85	99.93	12.91
7	2/2/2016 10:50 AM	19.3	0.17	50.17	31.85	99.94	12.91
8	2/2/2016 10:55 AM	19.31	0.16	46.58	31.85	99.95	12.87
9	2/2/2016 11:00 AM	34.04	0.11	58.35	31.85	99.95	12.91
10	2/2/2016 11:05 AM	41.28	0	0	31.85	99.93	12.90
11	2/2/2016 11:10 AM	42.23	0.08	50.88	31.85	99.94	12.89
12	2/2/2016 11:15 AM	40.16	0.1	59.13	31.92	99.93	12.91
13	2/2/2016 11:20 AM	39.83	0.1	57.23	31.92	99.93	12.90
14	2/2/2016 11:25 AM	39.16	0.09	52.14	31.92	99.93	12.90

Table 5: Data of level, flow & velocity for slope 1:500 (GPO)

Slope	Y (cm)	Y (m)	V (cm/s)	V (m/s)	Q (l/s)	Q (m3/s)	A, (m.sq)	Pw, (m)	R, (m)	n
0.002	19.17	0.19	0.16	0.16	45	0.045	0.288	1.883	0.153	0.080
0.002	22.65	0.23	0.15	0.15	50.71	0.051	0.340	1.953	0.174	0.093
0.002	21.64	0.22	0.13	0.13	41.3	0.041	0.325	1.933	0.168	0.105
0.002	19.96	0.20	0.16	0.16	47.72	0.048	0.299	1.899	0.158	0.082
0.002	19.46	0.19	00.14	0.14	42.11	0.042	0.292	1.889	0.155	0.092
0.002	19.3	0.19	0.17	0.17	50.17	0.050	0.290	1.886	0.153	0.075
0.002	19.31	0.19	0.16	0.16	46.58	0.047	0.290	1.886	0.154	0.080
0.002	34.04	0.34	0.11	0.11	58.35	0.058	0.511	2.181	0.234	0.154
0.002	0	0.00	0	0.00	0	0.000	0.000	0.000	0.000	#DIV/0!
0.002	42.23	0.42	0.08	0.08	50.88	0.051	0.633	2.345	0.270	0.234
0.002	40.16	0.40	0.1	0.10	59.13	0.059	0.602	2.303	0.262	0.183
0.002	39.83	0.40	0.1	0.10	57.23	0.057	0.597	2.297	0.260	0.182
0.002	39.16	0.39	0.09	0.09	52.14	0.052	0.587	2.283	0.257	0.201

Table 6: Data of R, Pw & Manning's n for slope 1:500 (GPO)

4.1.4 Slope 1:500 (Gate Fully Opening, GFO)

Data generated for duration of 1 hour (12.04 pm to 1.04 pm):

	A	B	C	D	E	F	G
1	Date Time	Level (cm)	Velocity (m/s)	Flow (L/s)	Temperature (°C)	Conductivity ()	Power Supply(V)
2	2/2/2016 12:04 PM	8.01	0.39	46.46	32.05	99.93	12.89
3	2/2/2016 12:09 PM	9.48	0.48	67.96	32.05	99.93	12.89
4	2/2/2016 12:14 PM	7.48	0.35	39.72	32.05	99.94	12.90
5	2/2/2016 12:19 PM	7.56	0.37	42.46	32.05	99.93	12.88
6	2/2/2016 12:24 PM	7.51	0.37	41.73	32.11	99.93	12.88
7	2/2/2016 12:29 PM	7.55	0.38	42.8	32.11	99.93	12.88
8	2/2/2016 12:34 PM	7.52	0.38	43.25	32.11	99.94	12.88
9	2/2/2016 12:39 PM	7.59	0.37	42.21	32.11	99.95	12.87
10	2/2/2016 12:44 PM	7.51	0.37	41.93	32.11	99.93	12.89
11	2/2/2016 12:49 PM	7.54	0.37	42.3	32.18	99.93	12.88
12	2/2/2016 12:54 PM	7.54	0.38	42.71	32.18	99.94	12.88
13	2/2/2016 12:59 PM	7.61	0.38	43	32.18	99.95	12.85
14	2/2/2016 1:04 PM	7.62	0.39	44.55	32.18	99.95	12.88

Table 7: Data of level, flow & velocity for slope 1:500 (GFO)

Slope	Y (cm)	Y (m)	V (m/s)	V (m/s)	Q (l/s)	Q (m3/s)	A, (m.sq)	Pw, (m)	R, (m)	n
0.002	8.01	0.08	0.39	0.39	46.46	0.046	0.120	1.660	0.072	0.020
0.002	9.48	0.09	0.48	0.48	67.96	0.068	0.142	1.690	0.084	0.018
0.002	7.48	0.07	0.35	0.35	39.72	0.040	0.112	1.650	0.068	0.021
0.002	7.56	0.08	0.37	0.37	42.46	0.042	0.113	1.651	0.069	0.020
0.002	7.51	0.08	0.37	0.37	41.73	0.042	0.113	1.650	0.068	0.020
0.002	7.55	0.08	0.38	0.38	42.8	0.043	0.113	1.651	0.069	0.020
0.002	7.52	0.08	0.38	0.38	43.25	0.043	0.113	1.650	0.068	0.020
0.002	7.59	0.08	0.37	0.37	42.21	0.042	0.114	1.652	0.069	0.020
0.002	7.51	0.08	0.37	0.37	41.93	0.042	0.113	1.650	0.068	0.020
0.002	7.54	0.08	0.37	0.37	42.3	0.042	0.113	1.651	0.069	0.020
0.002	7.54	0.08	0.38	0.38	42.71	0.043	0.113	1.651	0.069	0.020
0.002	7.61	0.08	0.38	0.38	43	0.043	0.114	1.652	0.069	0.020
0.002	7.62	0.08	0.39	0.39	44.55	0.045	0.114	1.652	0.069	0.019

Table 8: Data of R, Pw & Manning's n for slope 1:500 (GFO)

4.2 With Module

For data of flume without module, this data is by using two types of meter which is Current Meter and Acoustic Doppler Velocimeter (ADV).

4.2.1 Slope 1:1000 (Water Depth, d = 10 cm)

For d < 25 cm, the height of water will be factor with 0.4,

Data by using Current meter :

Module location	No. Of Module	Velocity (m/s)	Depth, d (Actual) (cm)	Depth,d (factor of 0.4) (cm)	Depth,d (Actual) (m)	Depth, d (factor of 0.4) (m)	L (m)	Pw (m)	A (m^2)	R	S	n
Front	1	0.23	7	2.8	0.07	0.028	1.5	1.556	0.042	0.027	0.001	0.012
	2	0.2	7	2.8	0.07	0.028	1.5	1.556	0.042	0.027	0.001	0.014
	3	0.23	7	2.8	0.07	0.028	1.5	1.556	0.042	0.027	0.001	0.012
Middle	1	0.21	6	2.4	0.06	0.024	1.5	1.548	0.036	0.023	0.001	0.012
	2	0.17	6	2.4	0.06	0.024	1.5	1.548	0.036	0.023	0.001	0.015
	3	0.17	6	2.4	0.06	0.024	1.5	1.548	0.036	0.023	0.001	0.015
End	1	0.24	5	2	0.05	0.02	1.5	1.540	0.03	0.019	0.001	0.010
	2	0.24	5	2	0.05	0.02	1.5	1.540	0.03	0.019	0.001	0.010
	3	0.25	5	2	0.05	0.02	1.5	1.540	0.03	0.019	0.001	0.009

Table 9: Data of level, flow & velocity for slope 1:1000 (10 cm)

Where, L- width of flume, Pw - Wetted Perimeter, A - cross sectional area

Data generated using Acoustic Doppler Velocimeter (ADV):

Slope	Y (cm)	Y (m)	V (m/s)	V (m/s)	Q (l/s)	Q (m3/s)	A, (m.sq)	Pw, (m)	R, (m)	n
0.001	1.46	0.01	0	0.00	0	0.000	0.022	1.529	0.014	#DIV/0!
0.001	1.48	0.01	0	0.00	0	0.000	0.022	1.530	0.015	#DIV/0!
0.001	7.79	0.08	0.2	0.20	23.37	0.023	0.117	1.656	0.071	0.027
0.001	6.39	0.06	0.2	0.20	19.29	0.019	0.096	1.628	0.059	0.024
0.001	6.25	0.06	0.2	0.20	18.97	0.019	0.094	1.625	0.058	0.024
0.001	6.3	0.06	0.2	0.20	18.64	0.019	0.095	1.626	0.058	0.024
0.001	6.33	0.06	0.19	0.19	18.39	0.018	0.095	1.627	0.058	0.025
0.001	6.32	0.06	0.18	0.18	16.84	0.017	0.095	1.626	0.058	0.026
0.001	6.29	0.06	0.2	0.20	18.77	0.019	0.094	1.626	0.058	0.024
0.001	6.27	0.06	0.19	0.19	17.85	0.018	0.094	1.625	0.058	0.025
0.001	6.23	0.06	0.19	0.19	17.56	0.018	0.093	1.625	0.058	0.025
0.001	6.18	0.06	0.18	0.18	16.41	0.016	0.093	1.624	0.057	0.026
0.001	6.11	0.06	0.17	0.17	15.56	0.016	0.092	1.622	0.056	0.027

Table 10: Data of R, Pw & Manning's n for slope 1:1000 (10 cm)

Data generated using Acoustic Doppler Velocimeter (ADV) for duration of 1 hour (2.08 pm to 3.08 pm):

	A	B	C	D	E	F	G	H	I	J	K	L
1	Date Time	Level(cm)	Velocity(m/s)	Flow(L/s)	Temperature (°C)	Conductivity( )	Level 2(cm)	Velocity 2(m/s)	Flow 2(L/s)	Temperature 2(°C)	Conductivity 2()	Power Supply(V)
2	26/10/2016 2:08 PM	01.11	00.00	00.00	30.88	28.18	01.46	00.00	00.00	31.46	27.90	15.05
3	26/10/2016 2:13 PM	05.03	00.05	03.50	30.94	99.95	01.48	00.00	00.00	31.40	99.96	15.05
4	26/10/2016 2:18 PM	11.21	00.07	11.72	31.01	100.00	07.79	00.20	23.37	31.14	99.98	15.04
5	26/10/2016 2:23 PM	10.21	00.06	08.49	31.33	99.99	06.39	00.20	19.29	31.33	99.95	15.05
6	26/10/2016 2:28 PM	10.25	00.07	10.88	31.40	100.00	06.25	00.20	18.97	31.46	99.97	15.06
7	26/10/2016 2:33 PM	10.28	00.05	08.25	31.40	99.95	06.30	00.20	18.64	31.40	99.95	15.06
8	26/10/2016 2:38 PM	10.30	00.04	06.65	31.33	100.00	06.33	00.19	18.39	31.33	99.94	15.06
9	26/10/2016 2:43 PM	10.25	00.06	09.41	31.27	100.00	06.32	00.18	16.84	31.27	99.92	15.05
10	26/10/2016 2:48 PM	10.24	00.06	09.10	31.27	99.98	06.29	00.20	18.77	31.20	99.97	15.01
11	26/10/2016 2:53 PM	10.21	00.07	10.24	31.27	99.94	06.27	00.19	17.85	31.20	99.95	15.05
12	26/10/2016 2:58 PM	10.20	00.06	09.06	31.27	99.95	06.23	00.19	17.56	31.27	99.93	15.07
13	26/10/2016 3:03 PM	10.18	00.06	09.62	31.27	99.96	06.18	00.18	16.41	31.27	99.93	15.06
14	26/10/2016 3:08 PM	10.15	00.07	11.33	31.27	99.99	06.11	00.17	15.56	31.27	99.94	15.04

Table 11: Data of level, flow & velocity for slope 1:1000 (10 cm)

4.2.2 Slope 1:1000 (Water Depth, d = 20 cm)

For d < 25 cm, the height of water will be factor with 0.4,

Data by using Current meter :

Module location	No. Of Module	Velocity (m/s)	Depth, d (Actual) (cm)	Depth,d (factor of 0.4) (cm)	Depth,d (Actual) (m)	Depth, d (factor of 0.4) (m)	L (m)	Pw (m)	A (m^2)	R	S	n
Front	1	0.12	16	6.4	0.16	0.064	1.5	1.628	0.096	0.059	0.001	0.040
	2	0.09	16	6.4	0.16	0.064	1.5	1.628	0.096	0.059	0.001	0.053
	3	0.13	16	6.4	0.16	0.064	1.5	1.628	0.096	0.059	0.001	0.037
Middle	1	0.14	15	6.0	0.15	0.060	1.5	1.620	0.090	0.056	0.001	0.033
	2	0.13	15	6.0	0.15	0.060	1.5	1.620	0.090	0.056	0.001	0.035
	3	0.14	15	6.0	0.15	0.060	1.5	1.620	0.090	0.056	0.001	0.033
End	1	0.16	13	5.2	0.13	0.052	1.5	1.604	0.078	0.049	0.001	0.026
	2	0.15	13	5.2	0.13	0.052	1.5	1.604	0.078	0.049	0.001	0.028
	3	0.15	13	5.2	0.13	0.052	1.5	1.604	0.078	0.049	0.001	0.028

Table 12: Data of level, flow & velocity for slope 1:1000 (20 cm)

Where, L- width of flume, Pw - Wetted Perimeter, A - cross sectional area

Data generated using Acoustic Doppler Velocimeter (ADV):

Slope	Y (cm)	Y (m)	V (m/s)	V (m/s)	Q (l/s)	Q (m3/s)	A, (m.sq)	Pw, (m)	R, (m)	n
0.001	2.28	0.02	0	0.00	0	0.000	0.034	1.546	0.022	#DIV/0!
0.001	15.74	0.16	0.16	0.16	36.93	0.037	0.236	1.815	0.130	0.051
0.001	19.98	0.20	0.13	0.13	38.99	0.039	0.300	1.900	0.158	0.071
0.001	18.98	0.19	0.14	0.14	38.56	0.039	0.285	1.880	0.151	0.064
0.001	19.55	0.20	0.13	0.13	36.81	0.037	0.293	1.891	0.155	0.070
0.001	18.52	0.19	0.15	0.15	42.7	0.043	0.278	1.870	0.149	0.059
0.001	18.34	0.18	0.15	0.15	39.95	0.040	0.275	1.867	0.147	0.059
0.001	18.39	0.18	0.15	0.15	40.65	0.041	0.276	1.868	0.148	0.059
0.001	18.56	0.19	0.15	0.15	42.22	0.042	0.278	1.871	0.149	0.059
0.001	18.7	0.19	0.14	0.14	37.92	0.038	0.281	1.874	0.150	0.064
0.001	18.76	0.19	0.15	0.15	43.33	0.043	0.281	1.875	0.150	0.060
0.001	18.7	0.19	0.15	0.15	40.83	0.041	0.281	1.874	0.150	0.059
0.001	18.55	0.19	0.15	0.15	42.77	0.043	0.278	1.871	0.149	0.059

Table 13: Data of R, Pw & Manning's n for slope 1:1000 (20 cm)

Data generated using Acoustic Doppler Velocimeter (ADV) for duration of 1 hour (3.25 pm to 4.25 pm):

	A	B	C	D	E	F	G	H	I	J	K	L
1	Date Time	Level(cm)	Velocity(m/s)	Flow(L/s)	Temperature (°C)	Conductivity( )	Level 2(cm)	Velocity 2(m/s)	Flow 2(L/s)	Temperature 2(°C)	Conductivity 2()	Power Supply(V)
2	26/10/2016 3:25 PM	04.25	00.03	01.65	31.27	99.66	02.49	00.00	00.00	31.14	97.27	15.06
3	26/10/2016 3:30 PM	16.08	00.09	22.61	31.27	99.94	11.88	00.15	26.79	31.20	99.96	15.06
4	26/10/2016 3:35 PM	21.14	00.06	18.76	31.27	99.94	20.16	00.13	39.38	31.20	99.93	15.05
5	26/10/2016 3:40 PM	20.03	00.08	23.33	31.27	99.92	18.98	00.15	41.52	31.20	99.94	15.06
6	26/10/2016 3:45 PM	20.81	00.06	18.43	31.20	99.98	19.69	00.13	38.34	31.20	99.94	15.06
7	26/10/2016 3:50 PM	19.79	00.06	18.66	31.20	99.96	18.62	00.15	41.22	31.20	99.97	15.07
8	26/10/2016 3:55 PM	19.57	00.06	17.82	31.20	99.94	18.34	00.16	43.38	31.14	99.95	15.03
9	26/10/2016 4:00 PM	19.60	00.07	20.30	31.20	99.98	18.37	00.15	40.02	31.20	99.94	15.06
10	26/10/2016 4:05 PM	19.70	00.07	20.42	31.20	99.94	18.51	00.15	42.09	31.14	99.95	15.05
11	26/10/2016 4:10 PM	19.85	00.07	20.60	31.20	99.96	18.69	00.14	37.89	31.20	99.93	15.07
12	26/10/2016 4:15 PM	19.94	00.05	16.31	31.20	99.98	18.76	00.15	43.33	31.20	99.96	15.08
13	26/10/2016 4:20 PM	19.87	00.07	21.87	31.20	99.94	18.72	00.15	43.23	31.14	99.94	15.04
14	26/10/2016 4:25 PM	19.77	00.06	18.63	31.20	99.98	18.58	00.15	42.87	31.20	99.97	15.05

Table 14: Data of level, flow & velocity for slope 1:1000 (20 cm)

4.2.3 Slope 1:1000 (Water Depth, d = 30 cm)

For d > 25 cm, the height of water will be taken at 0.2y, 0.6y and 0.8y

Data by using Current meter :

Module location	No. Of Module	Velocity (m/s)			Depth,d (Actual) (cm)	Depth,d (Actual) (m)	L (m)	Pw (m)	A (m^2)	R	S	n		
		0.2y	0.6y	0.8y								0.2y	0.6y	0.8y
Front	1	0.19	0.17	0.18	28	0.28	1.5	2.06	0.420	0.204	0.001			
	2	0.18	0.16	0.14	28	0.28	1.5	2.06	0.420	0.204	0.001			
	3	0.19	0.15	0.16	28	0.28	1.5	2.06	0.420	0.204	0.001			
	Vavg (m/s)	0.19	0.16	0.16	28	0.28	1.5	2.06	0.420	0.204	0.001	0.059	0.068	0.068
Middle	1	0.15	0.16	0.17	27	0.27	1.5	2.04	0.405	0.199	0.001			
	2	0.16	0.17	0.16	27	0.27	1.5	2.04	0.405	0.199	0.001			
	3	0.16	0.15	0.15	27	0.27	1.5	2.04	0.405	0.199	0.001			
	Vavg (m/s)	0.16	0.16	0.16	27	0.27	1.5	2.04	0.405	0.199	0.001	0.069	0.067	0.067
End	1	0.16	0.18	0.17	26	0.26	1.5	2.02	0.39	0.193	0.001			
	2	0.18	0.19	0.19	26	0.26	1.5	2.02	0.39	0.193	0.001			
	3	0.17	0.18	0.17	26	0.26	1.5	2.02	0.39	0.193	0.001			
	Vavg (m/s)	0.17	0.18	0.18	26	0.26	1.5	2.02	0.39	0.193	0.001	0.062	0.058	0.060

Table 15: Data of level, flow & velocity for slope 1:1000 (30 cm)

Where, L- width of flume, Pw - Wetted Perimeter, A - cross sectional area

Data generated using Acoustic Doppler Velocimeter (ADV):

Slope	Y (cm)	Y (m)	V (m/s)	V (m/s)	Q (l/s)	Q (m3/s)	A, (m.sq)	Pw, (m)	R, (m)	n
0.001	28.95	0.29	0.13	0.13	56.32	0.056	0.434	2.079	0.209	0.086
0.001	29.68	0.30	0.13	0.13	57.93	0.058	0.445	2.094	0.213	0.087
0.001	28.73	0.29	0.13	0.13	56.8	0.057	0.431	2.075	0.208	0.085
0.001	28.46	0.28	0.11	0.11	48.71	0.049	0.427	2.069	0.206	0.100
0.001	29.76	0.30	0.13	0.13	58.1	0.058	0.446	2.095	0.213	0.087
0.001	31.3	0.31	0	0.00	0	0.000	0.470	2.126	0.221	#DIV/0!
0.001	29.16	0.29	0.07	0.07	32.73	0.033	0.437	2.083	0.210	0.160
0.001	28.16	0.28	0.12	0.12	50.91	0.051	0.422	2.063	0.205	0.092
0.001	29.07	0.29	0.06	0.06	25.9	0.026	0.436	2.081	0.209	0.186
0.001	29.18	0.29	0.16	0.16	69.34	0.069	0.438	2.084	0.210	0.070
0.001	28.86	0.29	0.09	0.09	38.05	0.038	0.433	2.077	0.208	0.124
0.001	28.34	0.28	0.11	0.11	47.54	0.048	0.425	2.067	0.206	0.100
0.001	28.2	0.28	0.09	0.09	38.7	0.039	0.423	2.064	0.205	0.122

Table 16: Data of R, Pw & Manning's n for slope 1:1000 (30 cm)

Data generated using Acoustic Doppler Velocimeter (ADV) for duration of 1 hour (11.44 am to 12.44 pm):

	A	B	C	D	E	F	G	H	I	J	K	L
1	Date Time	Level(cm)	Velocity(m/s)	Flow(L/s)	Temperature (°C)	Conductivity( )	Level 2(cm)	Velocity 2(m/s)	Flow 2(L/s)	Temperature 2(°C)	Conductivity 2()	Power Supply(V)
2	10/11/2016 11:44 AM	29.86	00.06	26.69	29.84	99.94	28.95	00.13	56.32	29.84	99.95	15.05
3	10/11/2016 11:49 AM	30.50	00.00	00.00	29.84	99.95	29.68	00.13	57.93	29.90	99.95	15.05
4	10/11/2016 11:54 AM	29.24	00.06	27.03	29.90	99.96	28.73	00.13	56.80	29.90	99.95	15.06
5	10/11/2016 11:59 AM	29.06	00.00	00.00	29.97	99.92	28.46	00.11	48.71	29.90	99.93	15.06
6	10/11/2016 12:04 PM	30.50	00.03	15.18	29.97	99.95	29.76	00.13	58.10	29.97	99.94	15.03
7	10/11/2016 12:09 PM	32.11	00.00	00.00	29.97	99.96	31.30	00.00	00.00	30.03	99.96	15.07
8	10/11/2016 12:14 PM	29.70	00.05	22.10	29.97	99.92	29.16	00.07	32.73	30.03	99.94	15.06
9	10/11/2016 12:19 PM	28.69	00.06	27.41	30.03	99.92	28.16	00.12	50.91	30.03	99.95	15.05
10	10/11/2016 12:24 PM	29.65	00.06	28.43	30.03	99.92	29.07	00.06	25.90	29.97	99.93	15.06
11	10/11/2016 12:29 PM	29.71	00.02	10.81	30.03	99.98	29.18	00.16	69.34	30.03	99.96	15.06
12	10/11/2016 12:34 PM	29.42	00.04	17.98	30.10	99.96	28.86	00.09	38.05	30.03	99.94	15.05
13	10/11/2016 12:39 PM	28.85	00.00	00.00	30.10	99.93	28.34	00.11	47.54	30.10	99.95	15.05
14	10/11/2016 12:44 PM	28.72	00.00	00.00	30.10	99.96	28.20	00.09	38.70	30.10	99.96	15.06

Table 17: Data of level, flow & velocity for slope 1:1000 (30 cm)

4.2.4 Slope 1:500 (Water Depth, d = 10 cm)

For d < 25 cm, the height of water will be factor with 0.4,

Data by using Current meter :

Module location	No. Of Module	Velocity (m/s)	Depth, d (Actual) (cm)	Depth,d (factor of 0.4) (cm)	Depth,d (Actual) (m)	Depth, d (factor of 0.4) (m)	L (m)	Pw (m)	A (m^2)	R	S	n
Front	1	0.17	7	2.8	0.07	0.028	1.5	1.556	0.042	0.027	0.002	0.024
	2	0.12	7	2.8	0.07	0.028	1.5	1.556	0.042	0.027	0.002	0.034
	3	0.19	7	2.8	0.07	0.028	1.5	1.556	0.042	0.027	0.002	0.021
Middle	1	0.19	6	2.4	0.06	0.024	1.5	1.548	0.036	0.023	0.002	0.019
	2	0.19	6	2.4	0.06	0.024	1.5	1.548	0.036	0.023	0.002	0.019
	3	0.18	6	2.4	0.06	0.024	1.5	1.548	0.036	0.023	0.002	0.020
End	1	0.27	5	2	0.05	0.020	1.5	1.540	0.030	0.019	0.002	0.012
	2	0.28	5	2	0.05	0.020	1.5	1.540	0.030	0.019	0.002	0.012
	3	0.27	5	2	0.05	0.020	1.5	1.540	0.030	0.019	0.002	0.012

Table 18: Data of level, flow & velocity for slope 1:500 (10 cm)

Where, L- width of flume, Pw - Wetted Perimeter, A - cross sectional area

Data generated using Acoustic Doppler Velocimeter (ADV):

Slope	Y (cm)	Y (m)	V (m/s)	V (m/s)	Q (l/s)	Q (m3/s)	A, (m.sq)	Pw, (m)	R, (m)	n
0.002	2.48	0.02	0	0.00	0	0.000	0.037	1.550	0.024	#DIV/0!
0.002	4.51	0.05	0.15	0.15	10.16	0.010	0.068	1.590	0.043	0.036
0.002	9.19	0.09	0.2	0.20	26.95	0.027	0.138	1.684	0.082	0.042
0.002	8.4	0.08	0.19	0.19	23.85	0.024	0.126	1.668	0.076	0.042
0.002	8.31	0.08	0.19	0.19	23.33	0.023	0.125	1.666	0.075	0.042
0.002	8.27	0.08	0.17	0.17	21.59	0.022	0.124	1.665	0.074	0.047
0.002	8.27	0.08	0.17	0.17	21.59	0.022	0.124	1.665	0.074	0.047
0.002	8.22	0.08	0.18	0.18	22.35	0.022	0.123	1.664	0.074	0.044
0.002	8.21	0.08	0.17	0.17	20.49	0.020	0.123	1.664	0.074	0.046
0.002	8.18	0.08	0.16	0.16	19.97	0.020	0.123	1.664	0.074	0.049
0.002	8.21	0.08	0.18	0.18	22.09	0.022	0.123	1.664	0.074	0.044
0.002	8.21	0.08	0.18	0.18	22.09	0.022	0.123	1.664	0.074	0.044
0.002	8.23	0.08	0.19	0.19	22.85	0.023	0.123	1.665	0.074	0.042

Table 19: Data of R, Pw & Manning's n for slope 1:500 (10 cm)

Data generated using Acoustic Doppler Velocimeter (ADV) for duration of 1 hour (2.10 pm to 3.10 pm):

	A	B	C	D	E	F	G	H	I	J	K	L
1	Date Time	Level(cm)	Velocity(m/s)	Flow(L/s)	Temperature (°C)	Conductivity( )	Level 2(cm)	Velocity 2(m/s)	Flow 2(L/s)	Temperature 2(°C)	Conductivity 2()	Power Supply(V)
2	10/11/2016 2:10 PM	01.21	00.00	00.00	30.62	20.39	02.48	00.00	00.00	31.01	29.81	15.07
3	10/11/2016 2:15 PM	07.80	00.04	04.62	30.42	99.99	04.51	00.15	10.16	30.68	99.94	15.06
4	10/11/2016 2:20 PM	10.93	00.04	06.96	30.36	99.96	09.19	00.20	26.95	30.36	99.98	15.04
5	10/11/2016 2:25 PM	10.20	00.06	09.06	30.29	99.96	08.40	00.19	23.85	30.29	99.94	15.05
6	10/11/2016 2:30 PM	10.16	00.00	00.00	30.29	99.93	08.31	00.19	23.33	30.29	99.94	15.06
7	10/11/2016 2:35 PM	10.18	00.08	12.53	30.29	99.99	08.27	00.17	21.59	30.29	99.93	15.06
8	10/11/2016 2:40 PM	10.15	00.05	08.14	30.29	99.97	08.27	00.17	21.59	30.29	99.95	15.06
9	10/11/2016 2:45 PM	10.14	00.05	07.69	30.36	99.95	08.22	00.18	22.35	30.29	99.95	15.05
10	10/11/2016 2:50 PM	10.15	00.07	10.75	30.36	99.93	08.21	00.17	20.49	30.29	99.94	15.06
11	10/11/2016 2:55 PM	10.14	00.00	00.00	30.36	99.96	08.18	00.16	19.97	30.29	99.95	15.06
12	10/11/2016 3:00 PM	10.14	00.08	12.77	30.36	99.95	08.21	00.18	22.09	30.36	99.94	15.07
13	10/11/2016 3:05 PM	10.18	00.08	12.82	30.36	99.92	08.21	00.18	22.09	30.36	99.95	15.07
14	10/11/2016 3:10 PM	10.19	00.06	08.61	30.36	99.96	08.23	00.19	22.85	30.36	99.94	15.07

Table 20: Data of level, flow & velocity for slope 1:500 (10 cm)

4.2.5 Slope 1:500 (Water Depth, d = 20 cm)

For d < 25 cm, the height of water will be factor with 0.4, Data by using Current meter :

Module location	No. Of Module	Velocity (m/s)	Depth, d (Actual) (cm)	Depth,d (factor of 0.4) (cm)	Depth,d (Actual) (m)	Depth, d (factor of 0.4) (m)	L (m)	Pw (m)	A (m^2)	R	S	n
Front	1	0.12	17	6.8	0.17	0.068	1.5	1.636	0.102	0.062	0.002	0.059
	2	0.09	17	6.8	0.17	0.068	1.5	1.636	0.102	0.062	0.002	0.078
	3	0.17	17	6.8	0.17	0.068	1.5	1.636	0.102	0.062	0.002	0.041
Middle	1	0.17	16	6.4	0.16	0.064	1.5	1.628	0.096	0.059	0.002	0.040
	2	0.12	16	6.4	0.16	0.064	1.5	1.628	0.096	0.059	0.002	0.056
	3	0.15	16	6.4	0.16	0.064	1.5	1.628	0.096	0.059	0.002	0.045
End	1	0.16	15	6	0.15	0.060	1.5	1.620	0.090	0.056	0.002	0.041
	2	0.15	15	6	0.15	0.060	1.5	1.620	0.090	0.056	0.002	0.043
	3	0.16	15	6	0.15	0.060	1.5	1.620	0.090	0.056	0.002	0.041

Table 21: Data of level, flow & velocity for slope 1:500 (20 cm)

Where, L- width of flume, Pw - Wetted Perimeter, A - cross sectional area

Data generated using Acoustic Doppler Velocimeter (ADV):

Slope	Y (cm)	Y (m)	V (m/s)	V (m/s)	Q (l/s)	Q (m3/s)	A, (m.sq)	Pw, (m)	R, (m)	n
0.002	21.2	0.21	0.15	0.15	46.4	0.046	0.318	1.924	0.165	0.090
0.002	22.98	0.23	0.12	0.12	41.97	0.042	0.345	1.960	0.176	0.117
0.002	22.37	0.22	0.12	0.12	40.72	0.041	0.336	1.947	0.172	0.115
0.002	23.19	0.23	0.16	0.16	55.07	0.055	0.348	1.964	0.177	0.088
0.002	16.64	0.17	0.15	0.15	37.31	0.037	0.250	1.833	0.136	0.079
0.002	21.23	0.21	0.16	0.16	51.84	0.052	0.318	1.925	0.165	0.084
0.002	20.32	0.20	0.14	0.14	42.31	0.042	0.305	1.906	0.160	0.094
0.002	19.79	0.20	0.13	0.13	38.57	0.039	0.297	1.896	0.157	0.100
0.002	19.8	0.20	0.14	0.14	41.09	0.041	0.297	1.896	0.157	0.093
0.002	20.01	0.20	0.15	0.15	44.08	0.044	0.300	1.900	0.158	0.087
0.002	20.17	0.20	0.15	0.15	46.4	0.046	0.303	1.903	0.159	0.087
0.002	20.17	0.20	0.13	0.13	40.04	0.040	0.303	1.903	0.159	0.101
0.002	20.1	0.20	0.14	0.14	41.77	0.042	0.302	1.902	0.159	0.094

Table 22: Data of R, Pw & Manning's n for slope 1:500 (20 cm)

Data generated using Acoustic Doppler Velocimeter (ADV) for duration of 1 hour (3.36 pm to 4.36 pm):

	A	B	C	D	E	F	G	H	I	J	K	L
1	Date Time	Level(cm)	Velocity(m/s)	Flow(L/s)	Temperature (°C)	Conductivity( )	Level 2(cm)	Velocity 2(m/s)	Flow 2(L/s)	Temperature 2(°C)	Conductivity 2()	Power Supply(V)
2	10/11/2016 3:36 PM	22.93	00.09	30.48	30.36	99.93	21.20	00.15	46.40	30.36	99.94	15.06
3	10/11/2016 3:41 PM	22.62	00.08	26.05	30.42	99.93	22.98	00.12	41.97	30.36	99.96	15.07
4	10/11/2016 3:46 PM	22.74	00.07	24.74	30.36	99.94	22.37	00.12	40.72	30.36	99.94	15.06
5	10/11/2016 3:51 PM	23.51	00.03	11.71	30.36	99.97	23.19	00.16	55.07	30.36	99.95	15.04
6	10/11/2016 3:56 PM	16.97	00.00	00.00	30.42	99.97	16.64	00.15	37.31	30.42	99.94	15.07
7	10/11/2016 4:01 PM	21.44	00.00	00.00	30.42	99.93	21.23	00.16	51.84	30.42	99.93	15.06
8	10/11/2016 4:06 PM	20.63	00.07	22.82	30.42	99.98	20.32	00.14	42.31	30.42	99.95	15.07
9	10/11/2016 4:11 PM	20.18	00.07	20.35	30.49	99.95	19.79	00.13	38.57	30.42	99.97	15.07
10	10/11/2016 4:16 PM	20.21	00.06	17.52	30.49	99.96	19.80	00.14	41.09	30.42	99.94	15.05
11	10/11/2016 4:21 PM	20.45	00.06	18.08	30.42	99.94	20.01	00.15	44.08	30.42	99.94	15.07
12	10/11/2016 4:26 PM	20.62	00.07	20.85	30.42	99.96	20.17	00.15	46.40	30.42	99.95	15.07
13	10/11/2016 4:31 PM	20.59	00.06	18.87	30.42	99.98	20.17	00.13	40.04	30.42	99.94	15.05
14	10/11/2016 4:36 PM	20.53	00.05	14.59	30.42	99.94	20.10	00.14	41.77	30.42	99.95	15.05

Table 23: Data of level, flow & velocity for slope 1:500 (20 cm)

4.2.6 Slope 1:500 (Water Depth, d = 30 cm)

For d > 25 cm, the height of water will be taken at 0.2y, 0.6y and 0.8y

Data by using Current meter :

Module location	No. Of Module	Velocity (m/s)			Depth,d (Actual) (cm)	Depth,d (Actual) (m)	L (m)	Pw (m)	A (m^2)	R	S	n		
		0.2y	0.6y	0.8y								0.2y	0.6y	0.8y
Front	1	0.18	0.19	0.15	27	0.27	1.5	2.04	0.405	0.199	0.002			
	2	0.12	0.18	0.14	27	0.27	1.5	2.04	0.405	0.199	0.002			
	3	0.15	0.17	0.14	27	0.27	1.5	2.04	0.405	0.199	0.002			
	Vavg (m/s)	0.15	0.18	0.14	27	0.27	1.5	2.04	0.405	0.199	0.002	0.101	0.085	0.106
Middle	1	0.14	0.18	0.18	26	0.26	1.5	2.02	0.390	0.193	0.002			
	2	0.12	0.17	0.18	26	0.26	1.5	2.02	0.390	0.193	0.002			
	3	0.13	0.16	0.17	26	0.26	1.5	2.02	0.390	0.193	0.002			
	Vavg (m/s)	0.13	0.17	0.18	26	0.26	1.5	2.02	0.390	0.193	0.002	0.115	0.088	0.085
End	1	0.13	0.15	0.15	25	0.25	1.5	2	0.375	0.188	0.002			
	2	0.13	0.17	0.16	25	0.25	1.5	2	0.375	0.188	0.002			
	3	0.13	0.17	0.14	25	0.25	1.5	2	0.375	0.188	0.002			
	Vavg (m/s)	0.13	0.16	0.15	25	0.25	1.5	2	0.375	0.188	0.002	0.113	0.090	0.098

Table 24: Data of level, flow & velocity for slope 1:500 (30 cm)

Where, L- width of flume, Pw - Wetted Perimeter, A - cross sectional area

Data generated using Acoustic Doppler Velocimeter (ADV):

Slope	Y (cm)	Y (m)	V (m/s)	V (m/s)	Q (l/s)	Q (m3/s)	A, (m.sq)	Pw, (m)	R, (m)	n
0.002	4	0.04	0.07	0.07	4.37	0.004	0.060	1.580	0.038	0.072
0.002	20.35	0.20	0.15	0.15	46.22	0.046	0.305	1.907	0.160	0.088
0.002	32.11	0.32	0.1	0.10	49.31	0.049	0.482	2.142	0.225	0.165
0.002	28.76	0.29	0.1	0.10	42.64	0.043	0.431	2.075	0.208	0.157
0.002	30.89	0.31	0.1	0.10	47.22	0.047	0.463	2.118	0.219	0.162
0.002	29.14	0.29	0.1	0.10	44.24	0.044	0.437	2.083	0.210	0.158
0.002	30.08	0.30	0.09	0.09	42.85	0.043	0.451	2.102	0.215	0.178
0.002	30.46	0.30	0.08	0.08	36.38	0.036	0.457	2.109	0.217	0.202
0.002	30.6	0.31	0.06	0.06	29.46	0.029	0.459	2.112	0.217	0.269
0.002	30.6	0.31	0.1	0.10	43.68	0.044	0.459	2.112	0.217	0.162
0.002	30.53	0.31	0	0.00	0	0.000	0.458	2.111	0.217	#DIV/0!
0.002	30.41	0.30	0.07	0.07	33.54	0.034	0.456	2.108	0.216	0.230
0.002	30.23	0.30	0.13	0.13	58.12	0.058	0.453	2.105	0.215	0.124

Table 25: Data of R, Pw & Manning's n for slope 1:500 (30 cm)

Data generated using Acoustic Doppler Velocimeter (ADV) for duration of 1 hour (11.44 am to 12.44 pm):

	A	B	C	D	E	F	G	H	I	J	K	L
1	Date Time	Level(cm)	Velocity(m/s)	Flow(L/s)	Temperature (°C)	Conductivity( )	Level 2(cm)	Velocity 2(m/s)	Flow 2(L/s)	Temperature 2(°C)	Conductivity 2()	Power Supply(V)
2	10/11/2016 4:51 PM	04.36	00.04	02.30	30.42	104.44	04.00	00.07	04.37	30.16	100.09	15.04
3	10/11/2016 4:56 PM	22.04	00.07	23.89	30.42	99.94	20.35	00.15	46.22	30.29	99.93	15.03
4	10/11/2016 5:01 PM	32.59	00.03	14.72	30.42	99.94	32.11	00.10	49.31	30.36	99.93	15.04
5	10/11/2016 5:06 PM	28.85	00.00	00.00	30.42	99.96	28.76	00.10	42.64	30.36	99.95	15.06
6	10/11/2016 5:11 PM	30.95	00.05	23.67	30.42	99.93	30.89	00.10	47.22	30.36	99.94	15.05
7	10/11/2016 5:16 PM	29.43	00.06	28.20	30.42	99.93	29.14	00.10	44.24	30.36	99.95	15.04
8	10/11/2016 5:21 PM	30.33	00.05	20.62	30.42	99.95	30.08	00.09	42.85	30.36	99.95	15.05
9	10/11/2016 5:26 PM	30.71	00.06	26.52	30.42	99.96	30.46	00.08	36.38	30.36	99.95	15.02
10	10/11/2016 5:31 PM	30.85	00.08	36.39	30.42	99.93	30.60	00.06	29.46	30.36	99.96	15.04
11	10/11/2016 5:36 PM	30.85	00.00	00.00	30.36	99.95	30.60	00.10	43.68	30.36	99.95	15.04
12	10/11/2016 5:41 PM	30.78	00.00	00.00	30.42	99.96	30.53	00.00	00.00	30.36	99.93	15.04
13	10/11/2016 5:46 PM	30.66	00.00	00.00	30.36	99.94	30.41	00.07	33.54	30.36	99.95	15.05
14	10/11/2016 5:51 PM	30.50	00.09	41.49	30.42	99.95	30.23	00.13	58.12	30.36	99.95	15.05

Table 26: Data of level, flow & velocity for slope 1:500 (30 cm)

4.3 Discussion

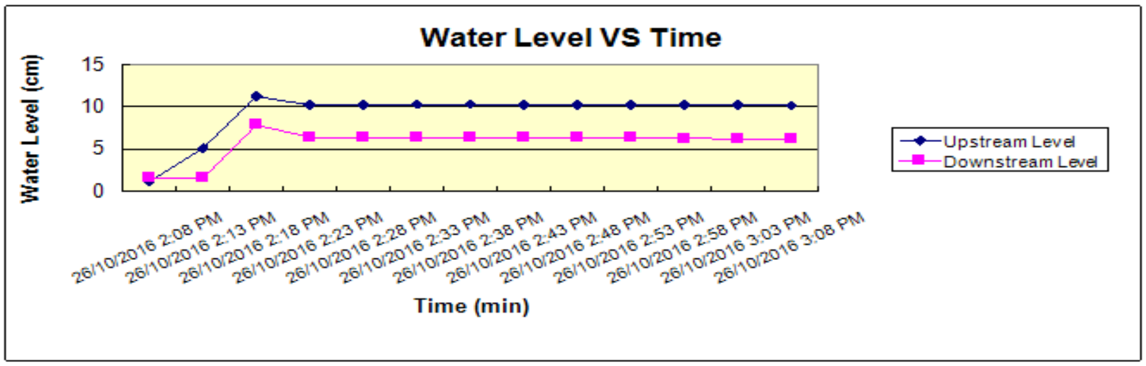
The data were collected for slope 1: 1000 with depth of water of 10 cm, 20 cm and

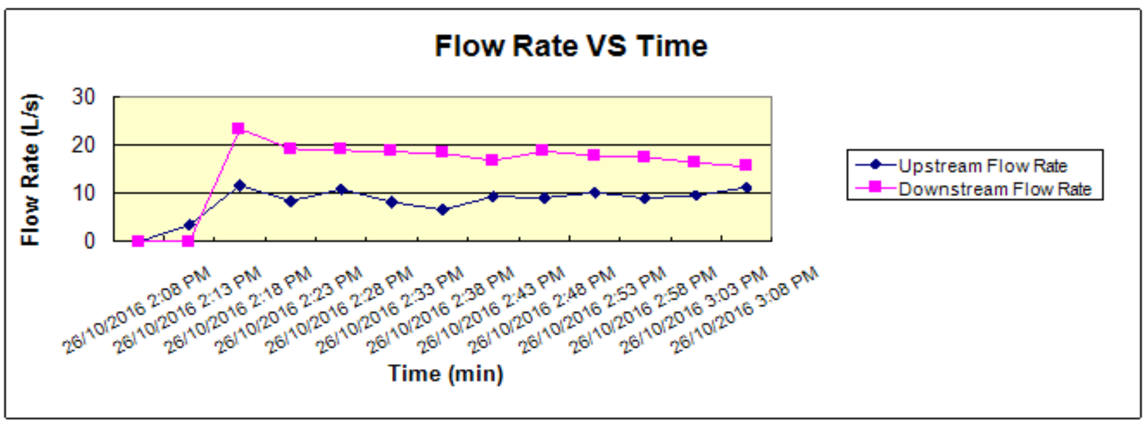
30 cm and also slope 1:500 with depth of water of 10 cm, 20 cm and 30 cm.The result and data will then be analyzed to evaluate the performance of the module under different parameter.

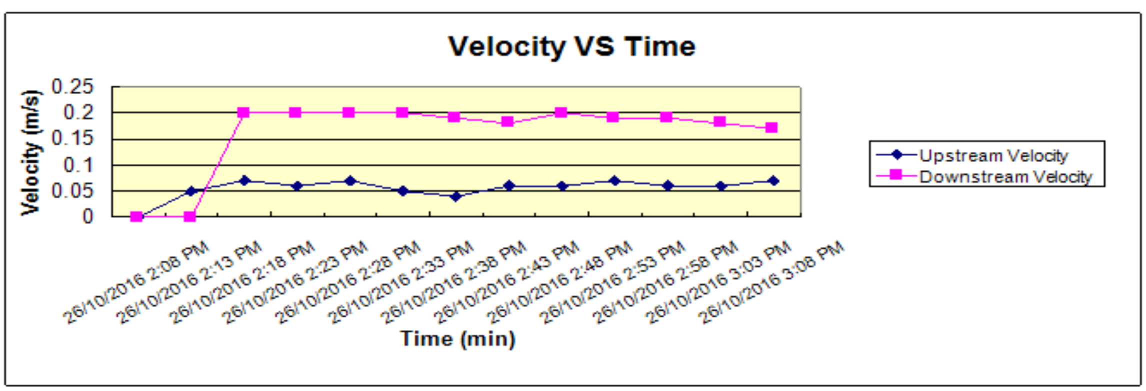
4.3.1 Data Analyze (Water level, Flow Rate & Velocity using Current Meter)

The flow resistance will be analyze by comparing the Velocity (m/s), Flow rate (L/s) and Water Level (cm) for water flow at upstream and downstream with respect to time.

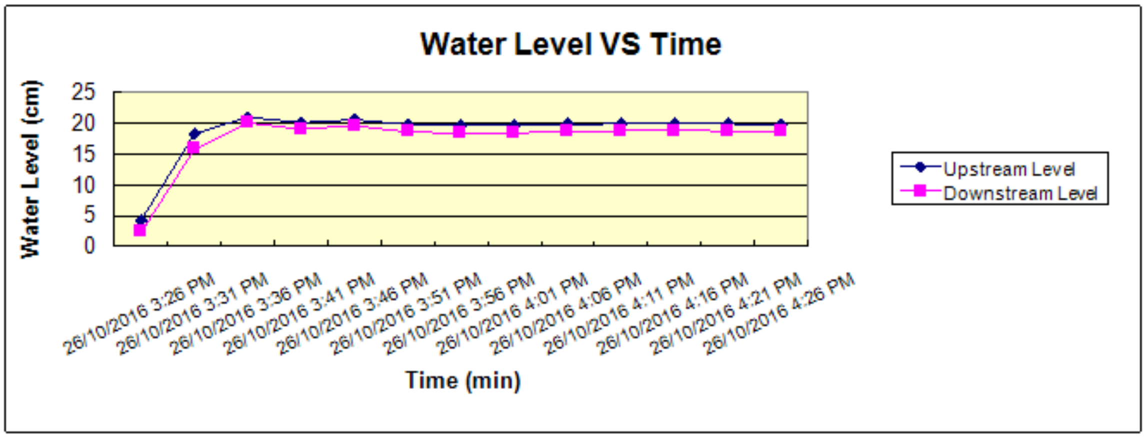
a) Slope 1:1000 (10 cm)

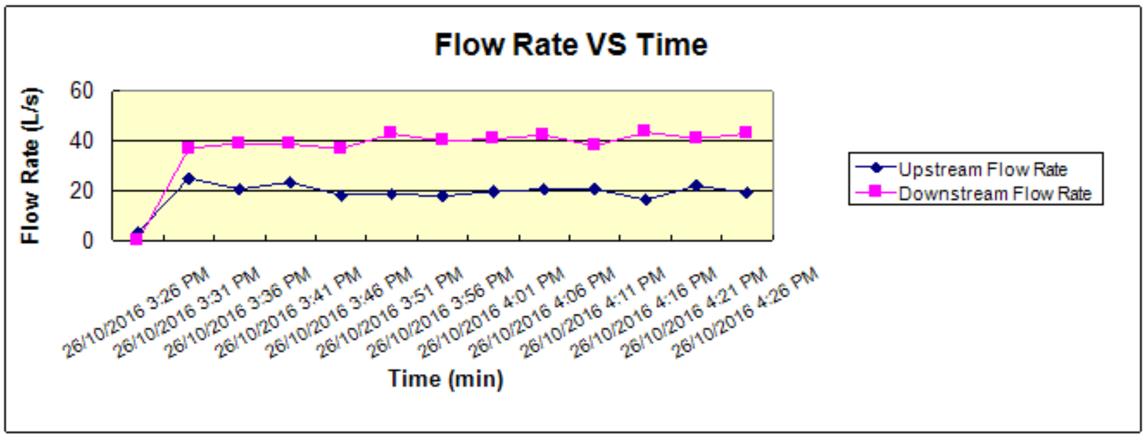


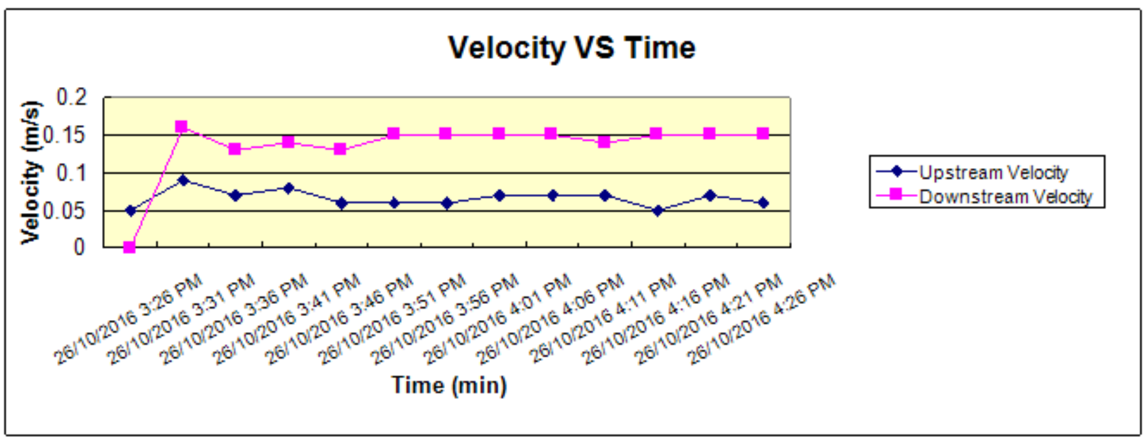




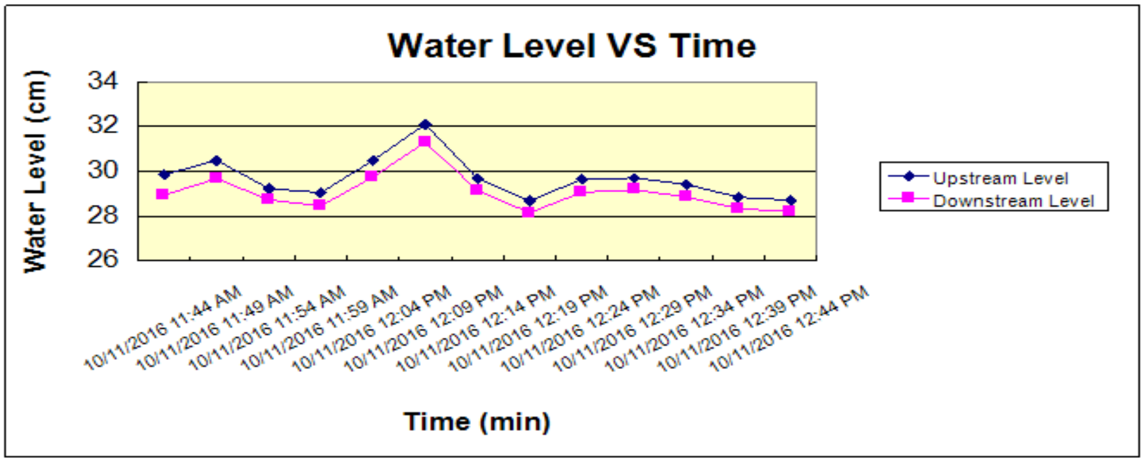
b) Slope 1:1000 (20 cm)

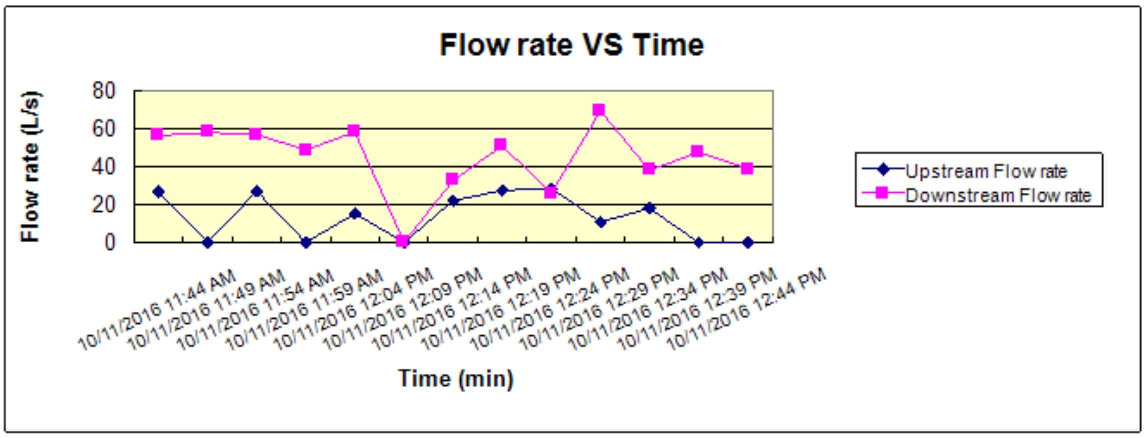


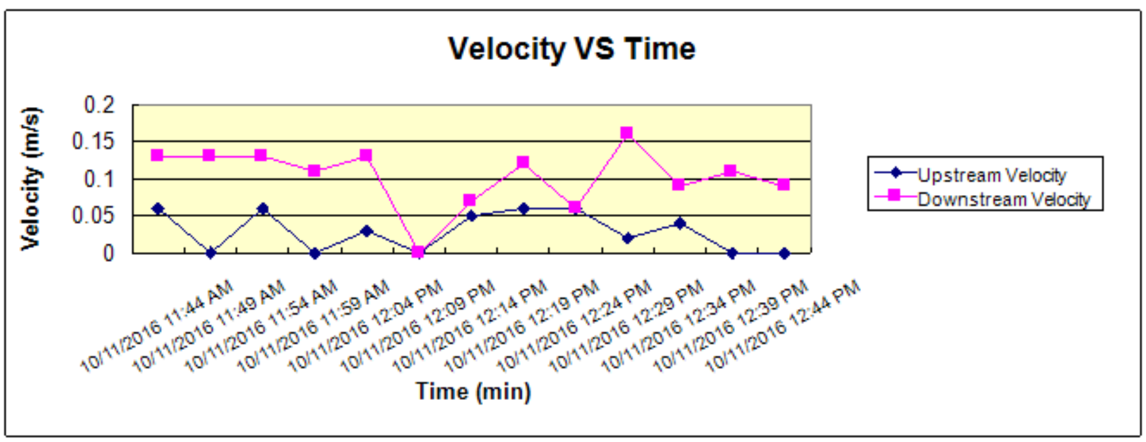




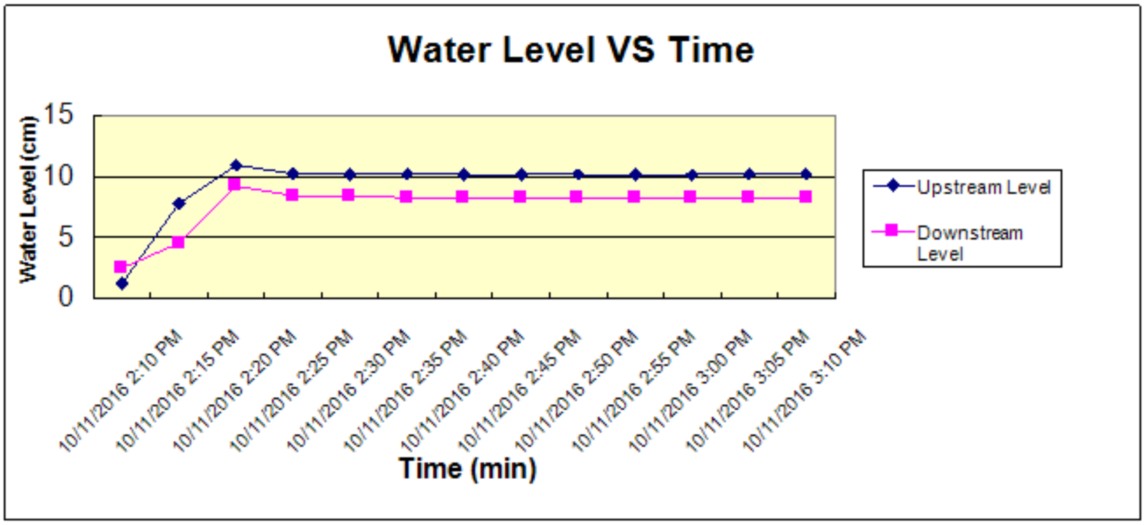
c) Slope 1:1000 (30 cm)

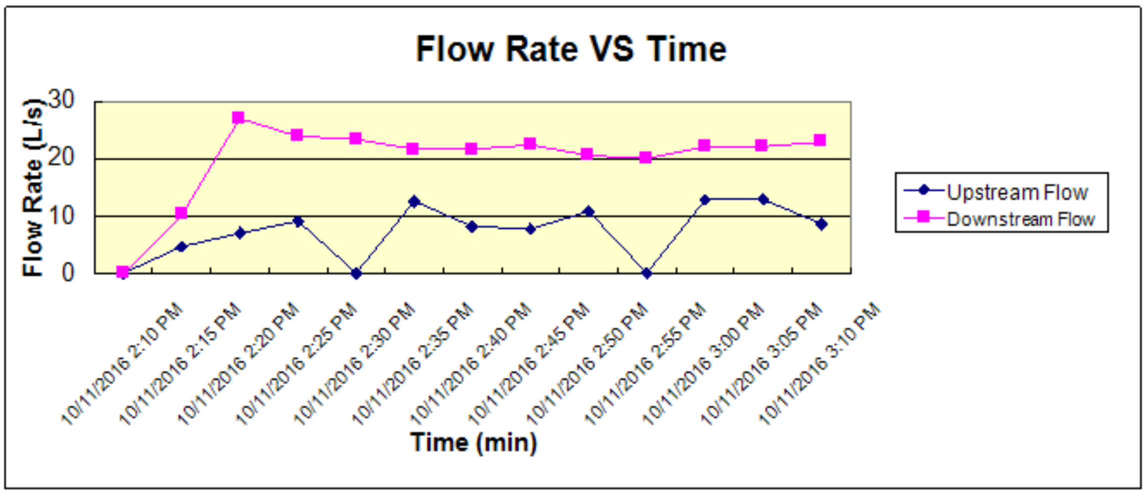


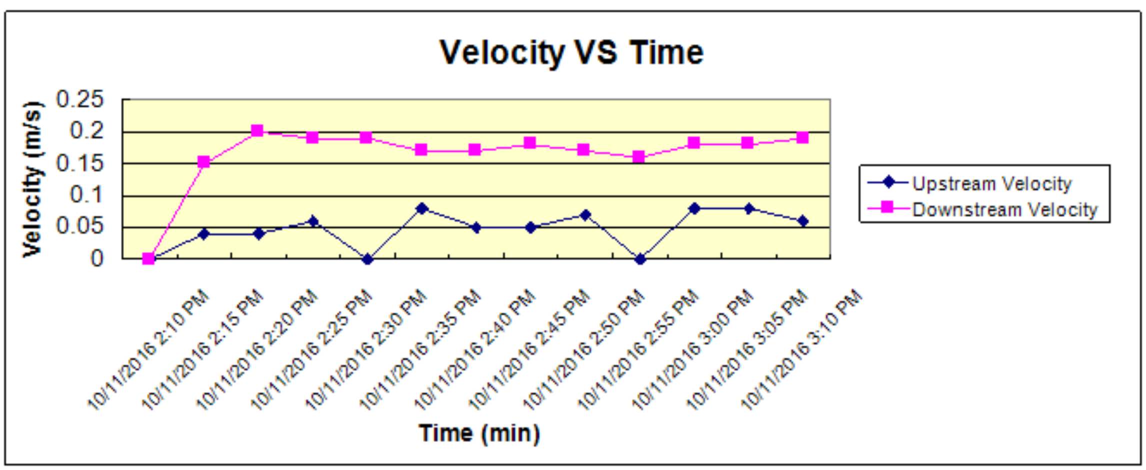




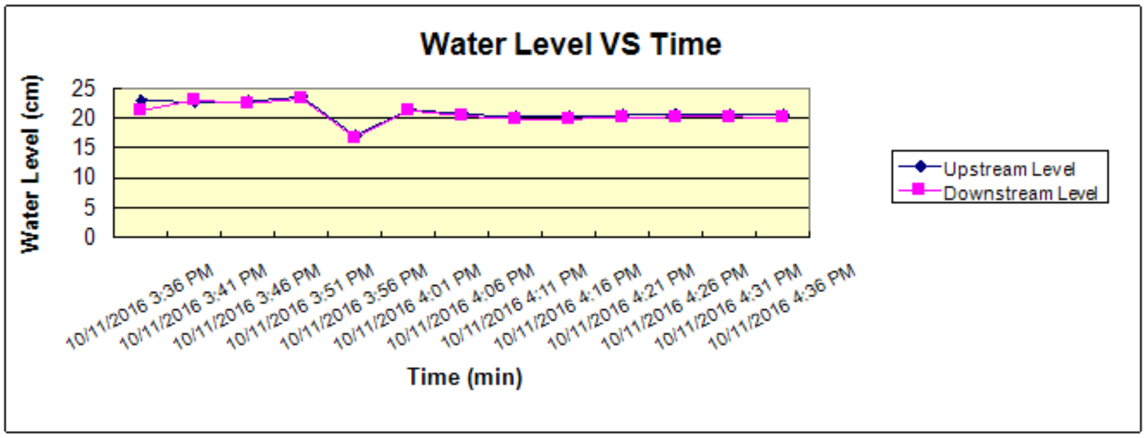
d) Slope 1:500 (10 cm)

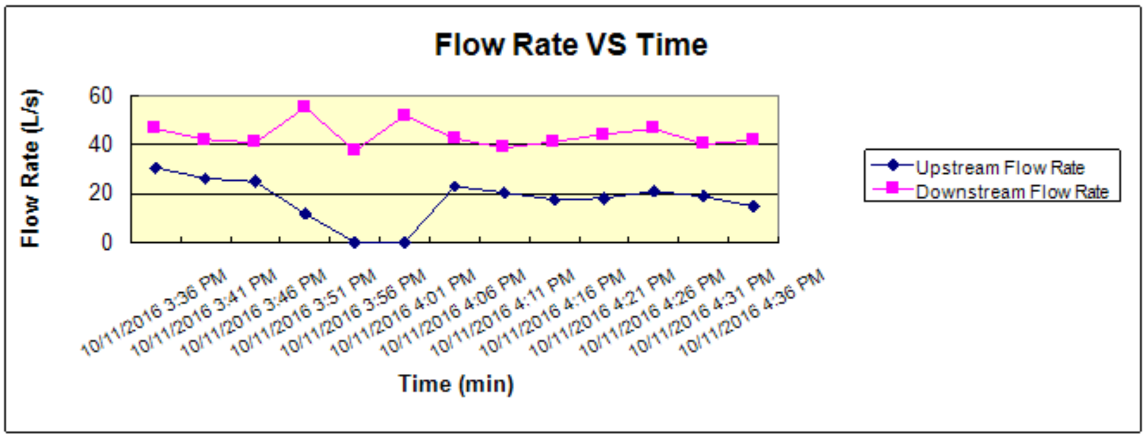


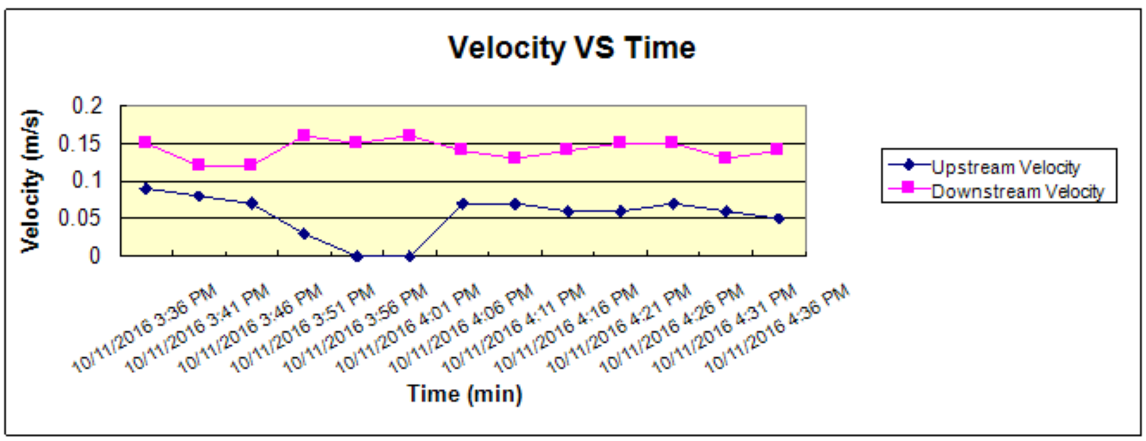




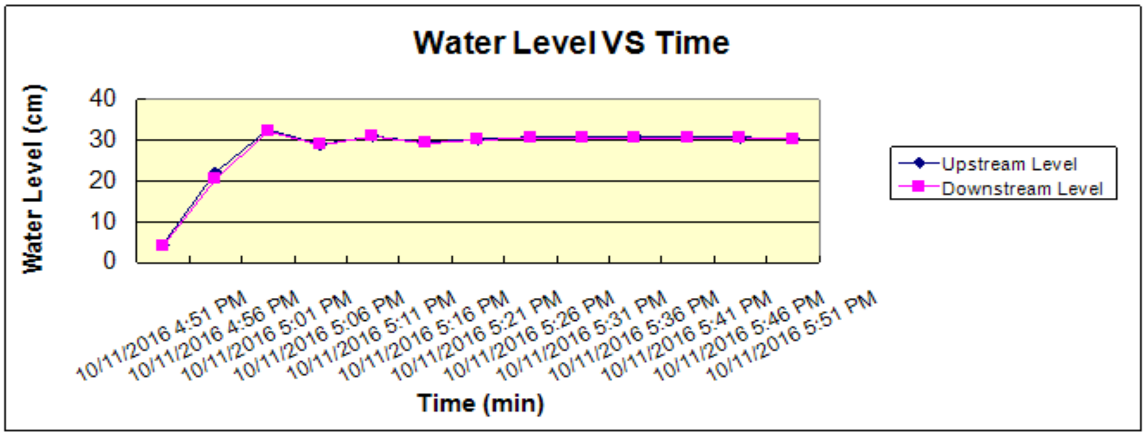
e) Slope 1:500 (20 cm)

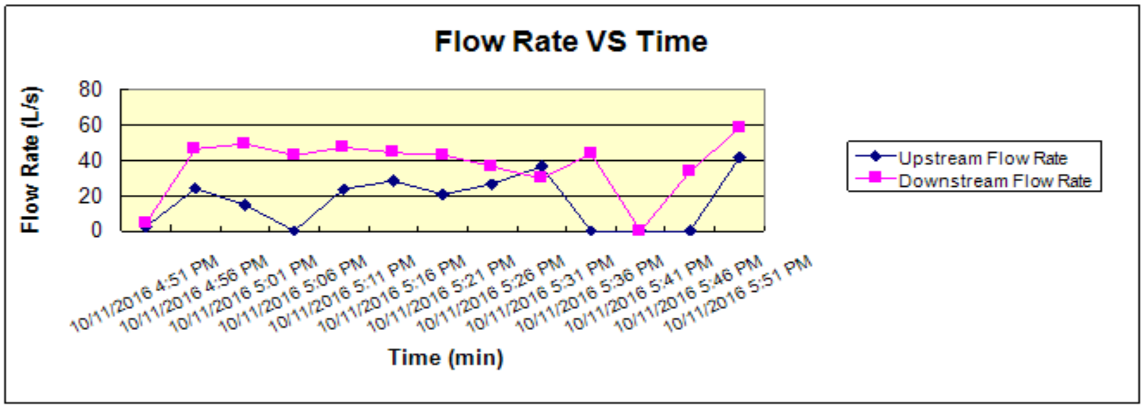


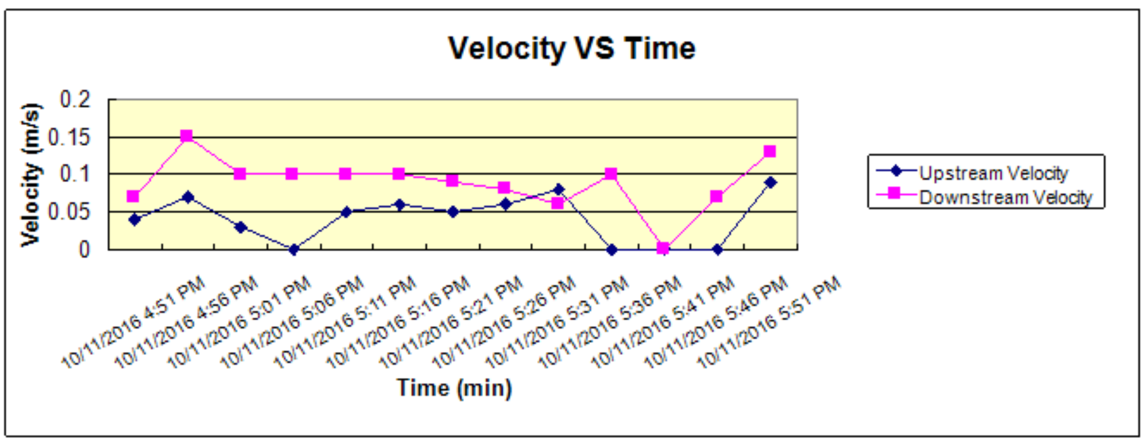




f) Slope 1:500 (30 cm)







From the graph shown above, water level at downstream decrease than the upstream level. The velocity and flow rate at downstream increase than the upstream. All of this graph show the ability of module to decrease the water level without hindering the velocity and flow rate of water. This will help to avoid flooding at downstream of the channel. The steeper slope (S = 0.0020) will affect the modular performance significantly than less steeper slope (S = 0.0010).

4.3.2 Data Analyze (Manning's n)

Data collection were done in two phase, without module and with module. For data of flume without module, the type of data were divided into Gate Partial Opening (GPO) and Gate Fully Opening (GFO) for each slope of 1/1000 and 1/500. For data of flume with module, the data consists of two series which is data from Current meter and Acoustic Doppler Velocimeter (ADV) for each slope of 1/1000 and 1/500.

Width of flume (mm)	Slope, S	Gate Opening	Range of Manning's n	Average Manning's n
1500	0.0010	Partial (GPO)	0.099-0.244	0.161
		Fully (GFO)	0.013-0.028	0.016
	0.0020	Partial (GPO)	0.075-0.234	0.130
		Fully (GFO)	0.018-0.021	0.020

Table 27: Manning's n for flume without modular channel using Acoustic Doppler Velocimeter (ADV)

Slope of S = 0.0010 has the highest Manning's n value which is 0.161 compare to slope of S = 0.0020 which is 0.030.

Width of flume (mm)	Slope, S	Water depth, d (m)	Range of Manning's n	Average Manning's n
1500	0.0010	0.1	0.024-0.027	0.025
		0.2	0.051-0.071	0.061
		0.3	0.070-0.186	0.108
	0.0020	0.1	0.036-0.049	0.044
		0.2	0.079-0.117	0.095
		0.3	0.072-0.269	0.164

Table 28: Manning's n for flume with modular channel using Acoustic Doppler Velocimeter (ADV)

Slope of S = 0.002 has the highest Manning's n value which is 0.164 compare to slope of S = 0.0010 which is 0.108.

Width of flume (mm)	Slope, S	Water depth, d (m)	Range of Manning's n	Average Manning's n
1500	0.0010	0.1	0.009-0.015	0.012
		0.2	0.026-0.053	0.035
		0.3	0.058-0.068	0.064
	0.0020	0.1	0.012-0.034	0.019
		0.2	0.040-0.078	0.049
		0.3	0.085-0.115	0.098

Table 29 : Manning's n for flume with modular channel (Current Meter)

Slope of S = 0.002 has the highest Manning's n value which is 0.098 compare to slope of S = 0.0010 which is 0.064.

4.3.2.1 Discussion of Manning's n value

By referring to Table 21 and Table 22, Manning's n value for flume with module is higher than Manning's n value for flume without module. This data verify the function of module to increase the Manning's n value.

4.3.3 Regression Analysis (R^2 and RMSE)

Regression analysis were done to determine the accurateness of Manning's n calculated by using the R^2 and RMSE. All of the data and Manning's n value were deemed to be eligible as all of R^2 value approaching to zero and all of RMSE value approaching to one.

Table 30: Categorization of model application results using correlation coefficient

Result Category	Correlation coefficient
Good results	**R≥ 0.80**
Moderately Strong	**0.60 ≥ R ≥ 0.80**
Moderate	**0.40 ≥ R ≥ 0.60**
Weak	0.20 ≥ R ≥ 0.40
Poor	R ≤ 0.20

Source: Shahin *et al.* [6]

4.3.3.1 R^2 and RMSE Value (Current Meter) - With Module

Results

	Samples	MSE	R
Training:	5	1.54698e-10	9.99982e-1
Validation:	2	9.87820e-11	1.00000e-0
Testing:	2	1.40724e-6	9.99999e-1

Results

	Samples	MSE	R
Training:	5	1.00367e-11	9.99999e-1
Validation:	2	1.42773e-4	1.00000e-0
Testing:	2	2.01570e-4	1.00000e-0

Figure 28: a) 1:1000 (10 cm) and b) 1:500 (10cm)

Results

	Samples	MSE	R
Training:	5	6.37667e-8	9.99641e-1
Validation:	2	1.72037e-9	1.00000e-0
Testing:	2	3.21289e-5	9.99999e-1

Results

	Samples	MSE	R
Training:	5	8.68344e-15	9.99999e-1
Validation:	2	4.39983e-6	9.99999e-1
Testing:	2	3.30693e-5	1.00000e-0

Figure 29: a) 1:1000 (20 cm) and b) 1:500 (20 cm)

Results

	Samples	MSE	R
Training:	5	4.00000e-7	9.86754e-1
Validation:	2	1.25889e-16	1.00000e-0
Testing:	2	2.43516e-6	1.00000e-0

Results

	Samples	MSE	R
Training:	5	5.62590e-15	9.99999e-1
Validation:	2	2.49466e-4	1.00000e-0
Testing:	2	3.35075e-5	1.00000e-0

Figure 30: a) 1:1000 (30 cm) and b) 1:500 (30 cm)

As shown above, all the result were accepted as the all R^2 value approaching to one and all the RMSE value approaching to zero.

4.3.3.2 R^2 and RMSE Value (Acoustic Doppler Velocimeter (ADV))- with Module

Results

	Samples	MSE	R
Training:	5	5.36251e-8	9.93805e-1
Validation:	3	1.94929e-7	9.99757e-1
Testing:	3	3.28471e-8	9.76249e-1

Results

	Samples	MSE	R
Training:	6	3.05396e-9	9.99963e-1
Validation:	3	4.26203e-9	9.99849e-1
Testing:	3	2.18401e-8	9.99977e-1

Figure 31: a) 1:1000 (10 cm) and b) 1:500 (10cm)

Results

	Samples	MSE	R
Training:	6	4.08569e-7	9.94257e-1
Validation:	3	2.56316e-7	9.90723e-1
Testing:	3	4.48136e-6	9.94305e-1

Results

	Samples	MSE	R
Training:	7	5.11014e-7	9.99220e-1
Validation:	3	1.32808e-6	9.90059e-1
Testing:	3	4.06614e-6	9.89897e-1

Figure 32: a) 1:1000 (20 cm) and b) 1:500 (20 cm)

Results

	Samples	MSE	R
Training:	6	7.41456e-18	9.99999e-1
Validation:	3	9.63807e-5	9.05043e-1
Testing:	3	1.66161e-5	9.56322e-1

Results

	Samples	MSE	R
Training:	6	2.37036e-8	9.99999e-1
Validation:	3	1.44476e-4	9.91039e-1
Testing:	3	1.82244e-4	9.97781e-1

Figure 33: a) 1:1000 (30 cm) and b) 1:500 (30 cm)

As shown above, all the result were accepted as the all R^2 value approaching to one and all the RMSE value approaching to zero.

4.3.3.3 R^2 and RMSE Value (Acoustic Doppler Velocimeter (ADV))- without Module

Results

	Samples	MSE	R
Training:	4	5.53463e-5	9.86716e-1
Validation:	3	1.50924e-4	9.40301e-1
Testing:	3	2.19950e-4	9.95807e-1

Results

	Samples	MSE	R
Training:	6	1.48583e-7	9.99973e-1
Validation:	3	8.16217e-5	9.99422e-1
Testing:	3	1.04644e-4	9.94900e-1

Figure 34: a) 1:1000 (GPO) and b) 1:500 (GPO)

Results

	Samples	MSE	R
Training:	6	1.68539e-8	9.98609e-1
Validation:	3	1.98245e-7	9.86268e-1
Testing:	3	4.78282e-7	9.99999e-1

Results

	Samples	MSE	R
Training:	5	5.69878e-8	8.18417e-1
Validation:	4	1.09724e-6	-9.79392e-1
Testing:	4	4.05426e-6	-9.92942e-1

Figure 35: a) 1:1000 (GFO) and b) 1:500 (GFO)

As shown above, all the result were accepted as the all R^2 value approaching to one and all the RMSE value approaching to zero.All of the RMSE and R2 value were generated by using Neural Network Fitting Tool in MATLAB. For Validation and Test Data, sample were divided by 50% for Training, 25% for Validation and remaining 25% for Testing.For the Train Network, the training algorithm that were used is Levenberg-Marquardt and the total hidden layer use is 10.

4.3.3.4 Regression graph (Current Meter)- with Module

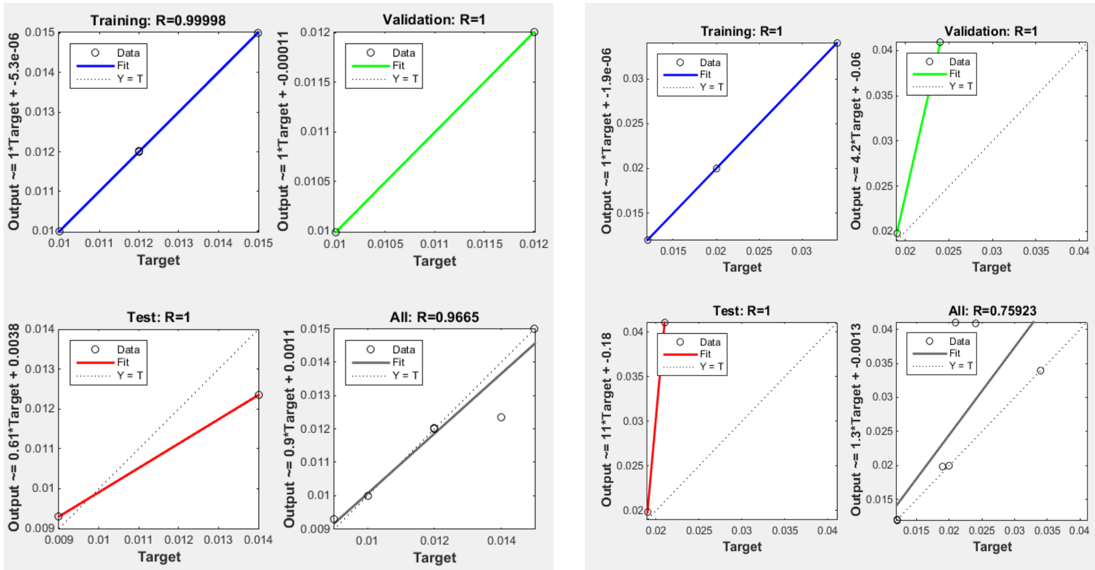


Figure 36: a) 1:1000 (10 cm) and b) 1:500 (10cm)

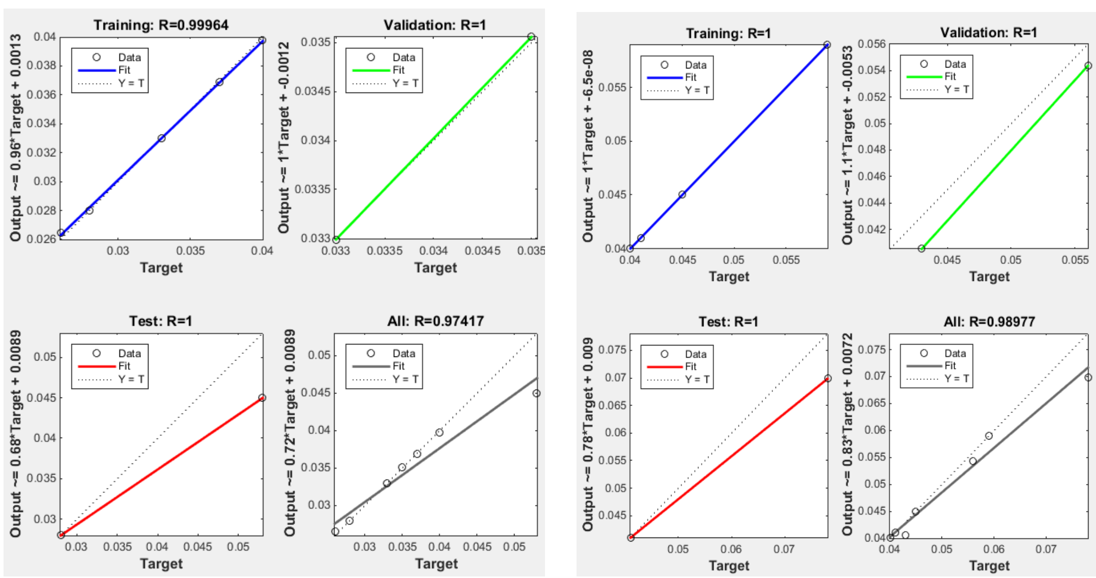


Figure 37: a) 1:1000 (20 cm) and b) 1:500 (20cm)

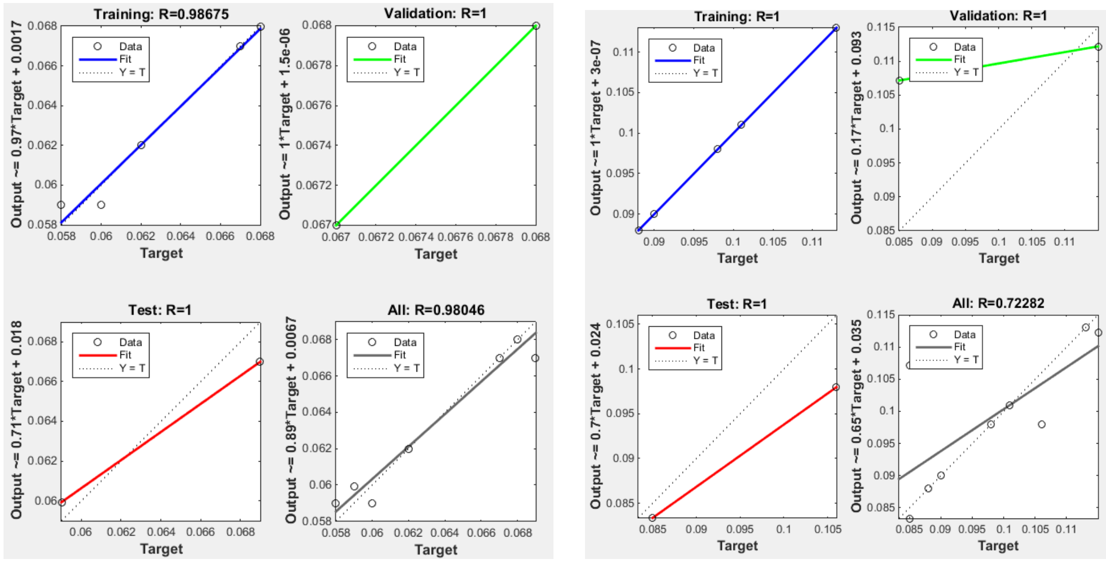


Figure 38 : a) 1:1000 (30 cm) and b) 1:500 (30cm)

From graph shown above, major of the R value for Training, Validation and Test approaching the best fit line. For some of graph that were not so close to the best fit line needed more data sample so more accurate result can be obtained.

4.3.3.5 Regression graph (Acoustic Doppler Velocimeter (ADV))- with Module

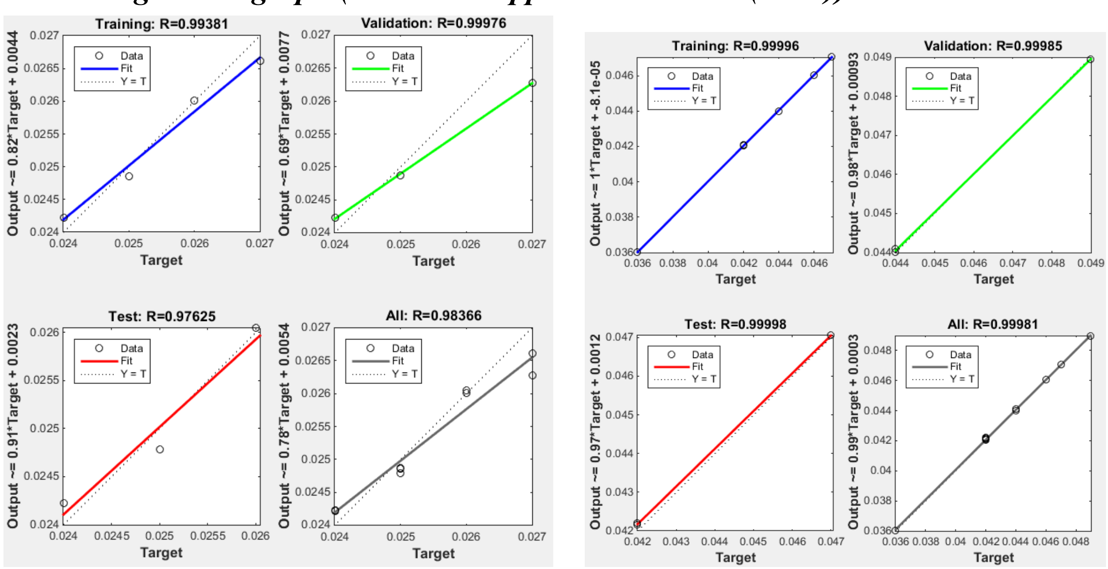


Figure 39: a) 1:1000 (10 cm) and b) 1:500 (10cm)

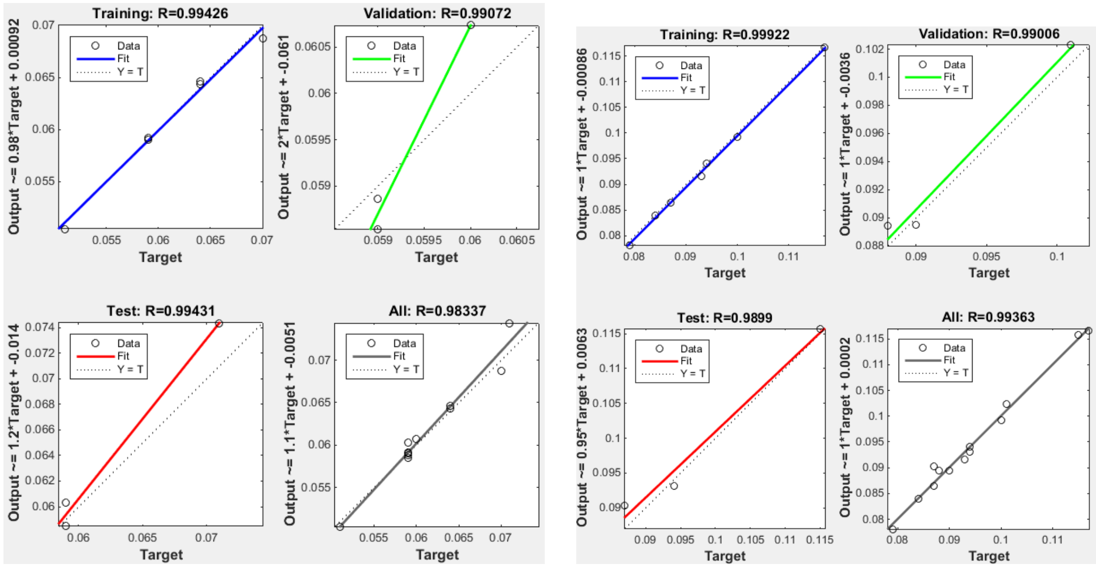


Figure 40: a) 1:1000 (20 cm) and b) 1:500 (20cm)

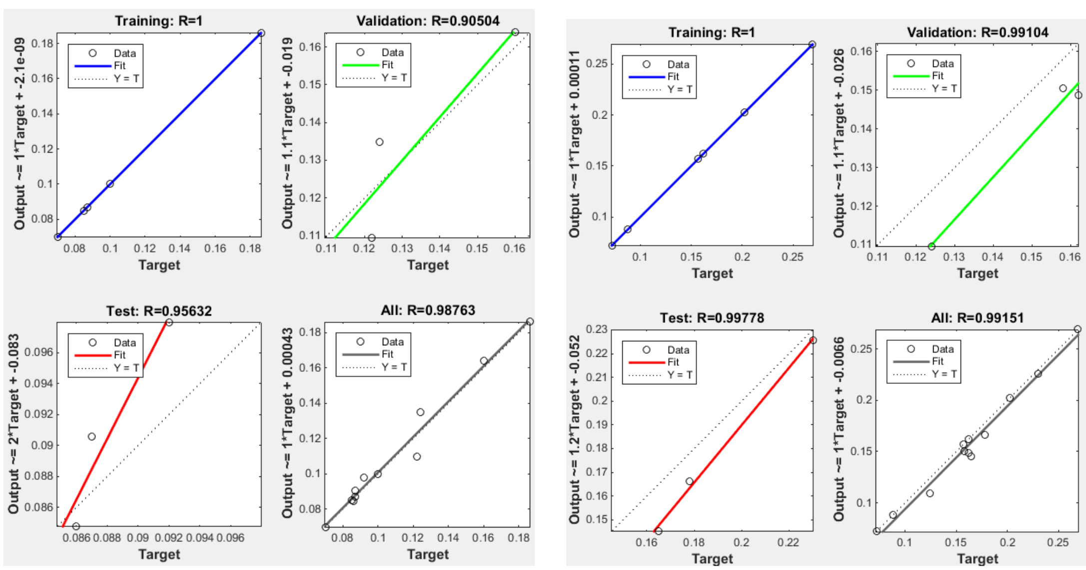


Figure 41 : a) 1:1000 (30 cm) and b) 1:500 (30cm)

From graph shown above, major of the R value for Training, Validation and Test approaching the best fit line. For some of graph that were not so close to the best fit line needed more data sample so more accurate result can be obtained.

4.3.3.6 Regression graph (Acoustic Doppler Velocimeter (ADV))- without Module

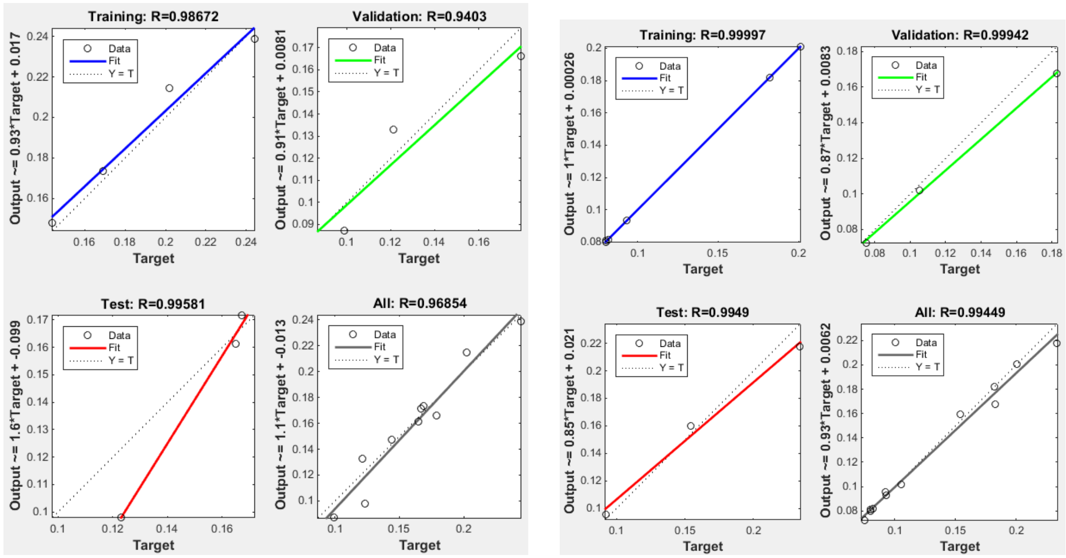


Figure 42: a) 1:1000 (GPO) and b) 1:500 (GPO)

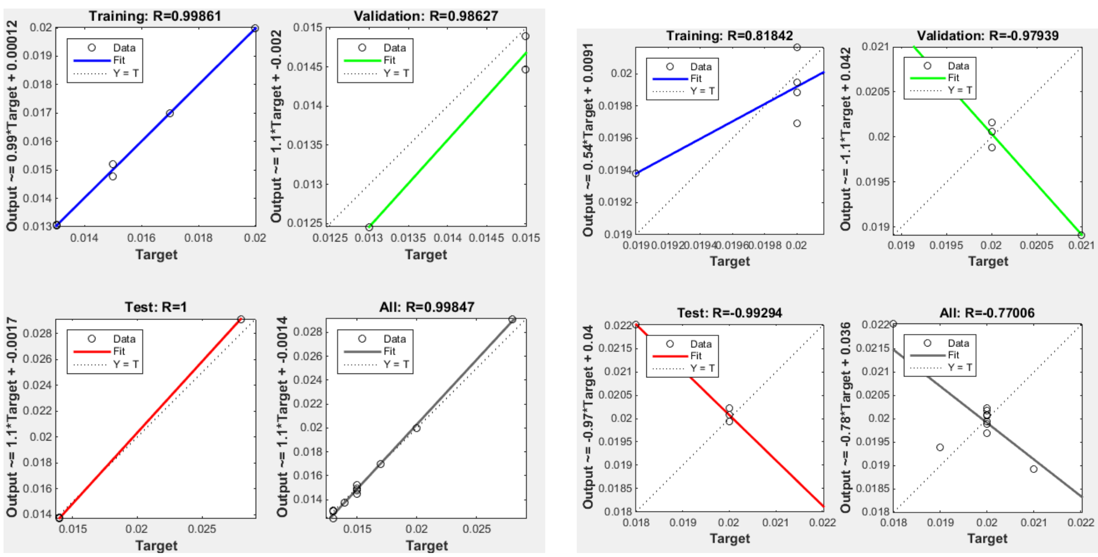


Figure 43: a) 1:1000 (GFO) and b) 1:500 (GFO)

From graph shown above, major of the R value for Training, Validation and Test approaching the best fit line. For some of graph that were not so close to the best fit line needed more data sample so more accurate result can be obtained.

4.3.3.7 Performance Graph (Current Meter)-with Module

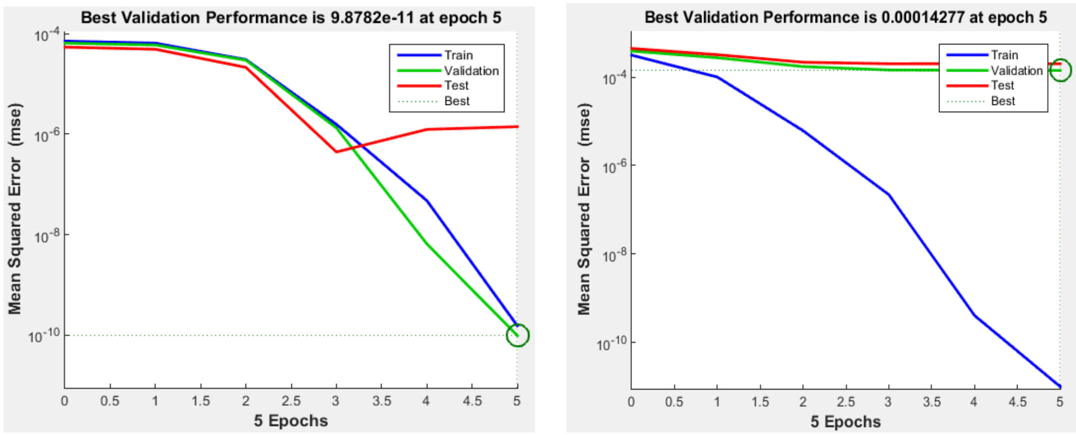


Figure 44: a) 1:1000 (10 cm) and b) 1:500 (10cm)

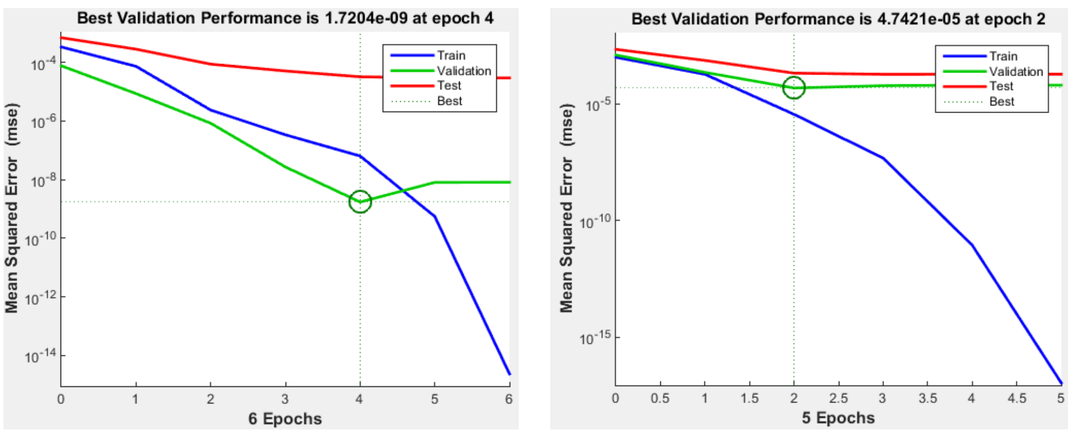


Figure 45: a) 1:1000 (20 cm) and b) 1:500 (20cm)

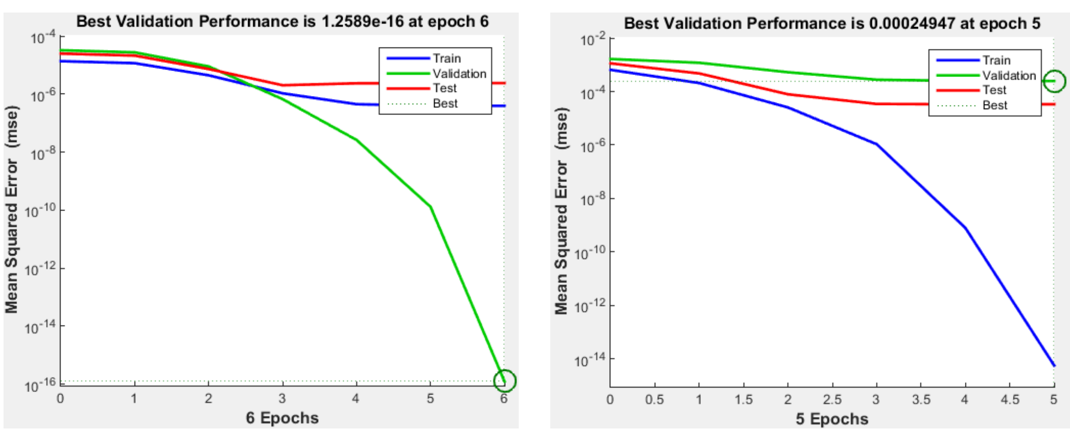


Figure 46: a) 1:1000 (30 cm) and b) 1:500 (30cm)

Graph above show the validation performance from running the data sample for each parameter. The train line were a bit far from best line due to less number of sample used.

4.3.3.8 Performance Graph (Acoustic Doppler Velocimeter (ADV))- with Module)

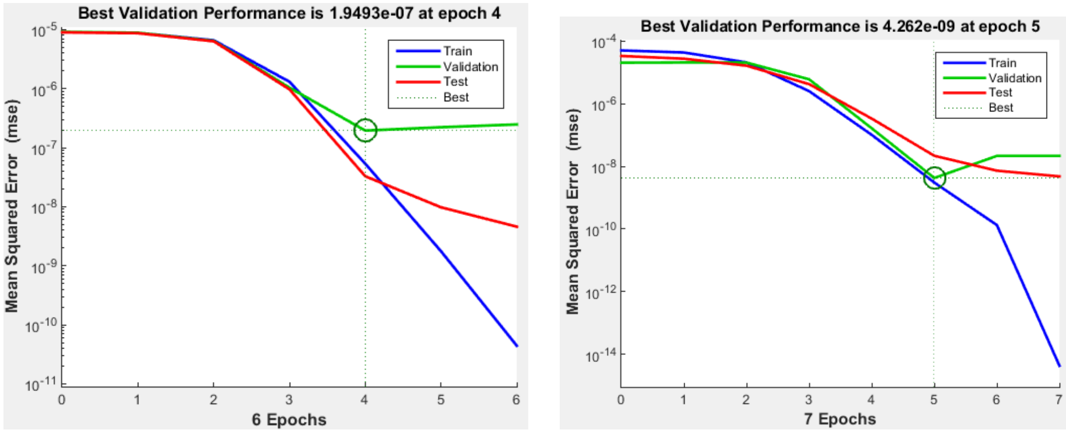


Figure 47: a) 1:1000 (10 cm) and b) 1:500 (10cm)

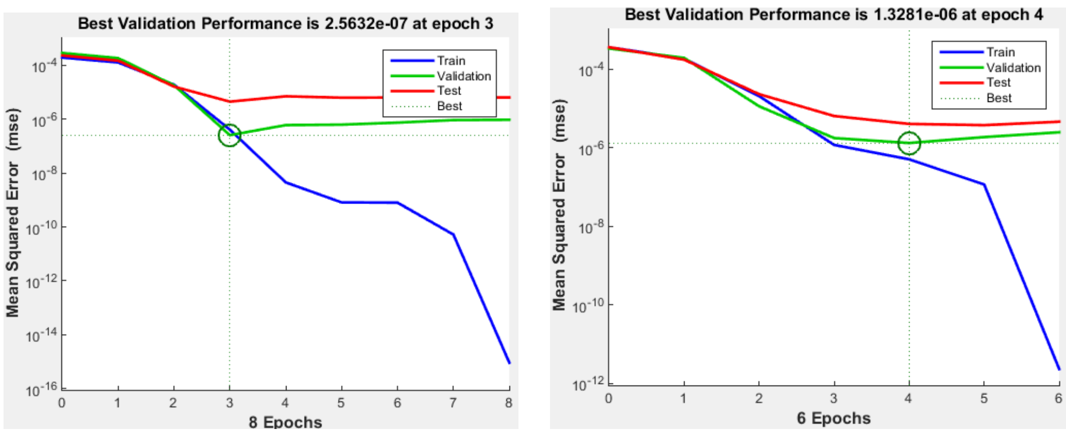


Figure 48: a) 1:1000 (20 cm) and b) 1:500 (20cm)

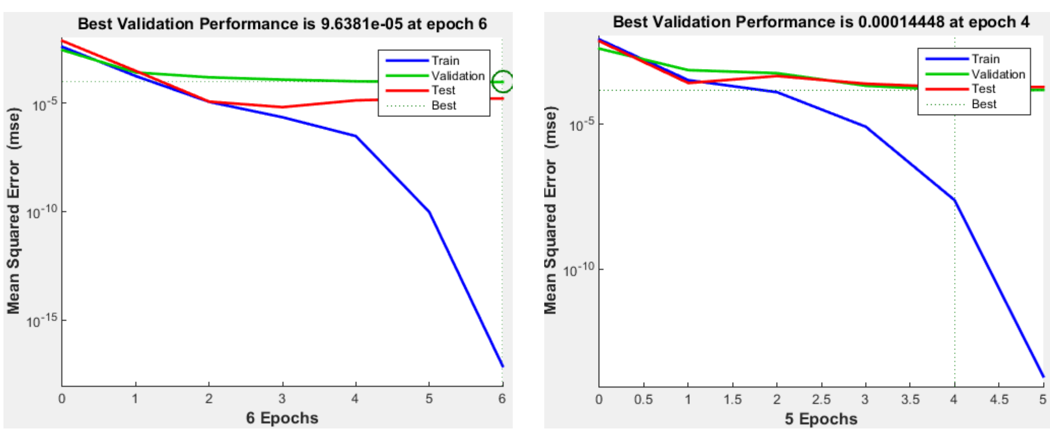


Figure 49: a) 1:1000 (30 cm) and b) 1:500 (30cm)

Graph above show the validation performance from running the data sample for each parameter. The train line were a bit far from best line due to less number of sample used.

4.3.3.9 Performance Graph (Acoustic Doppler Velocimeter (ADV))- without Module)

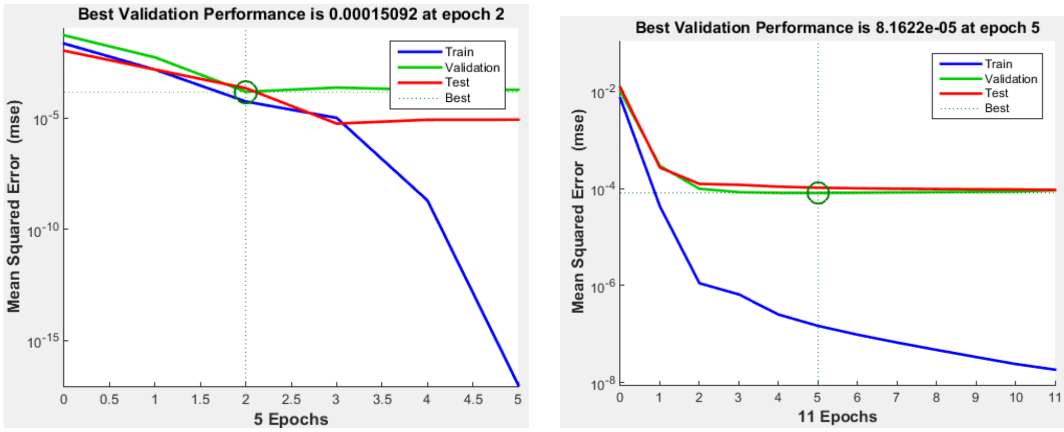


Figure 50: a) 1:1000 (GPO) and b) 1:500 (GPO)

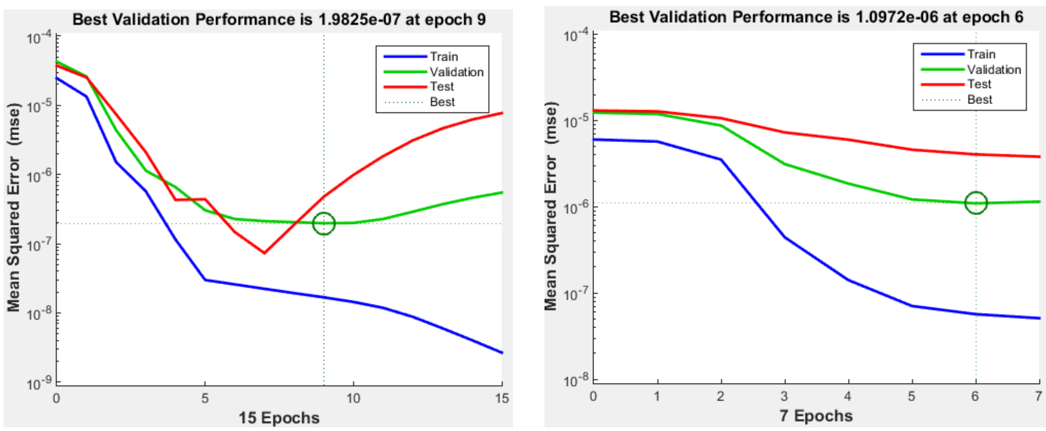


Figure 51: a) 1:1000 (GFO) and b) 1:500 (GFO)

Graph above show the validation performance from running the data sample for each parameter. The train line were a bit far from best line due to less number of sample used.

4.3.3.10 Error Graph (Current Meter)-with Module

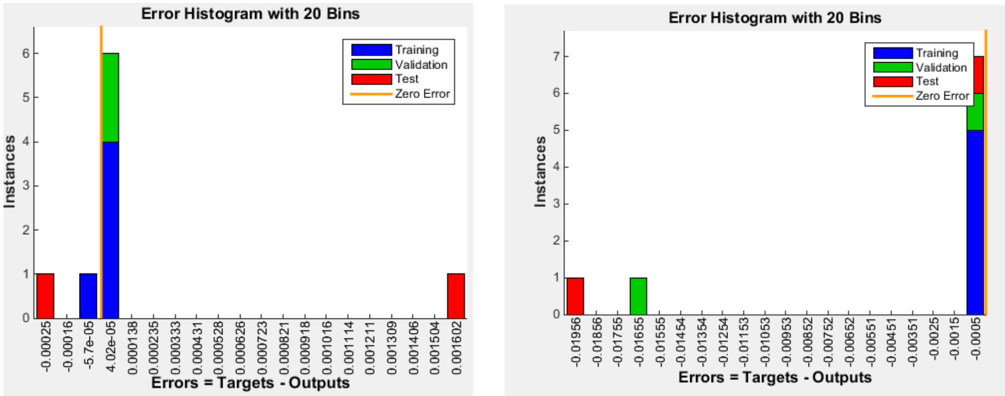


Figure 52: a) 1:1000 (10 cm) and b) 1:500 (10cm)

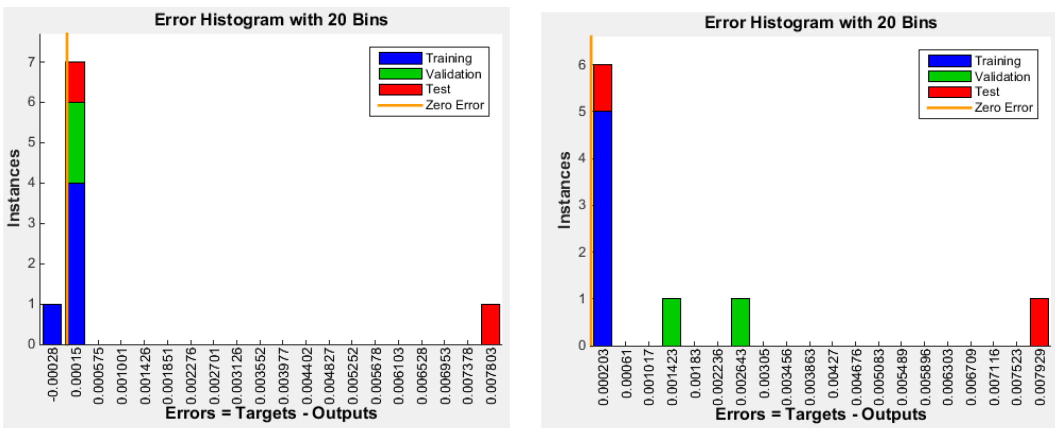


Figure 53: a) 1:1000 (20 cm) and b) 1:500 (20cm)

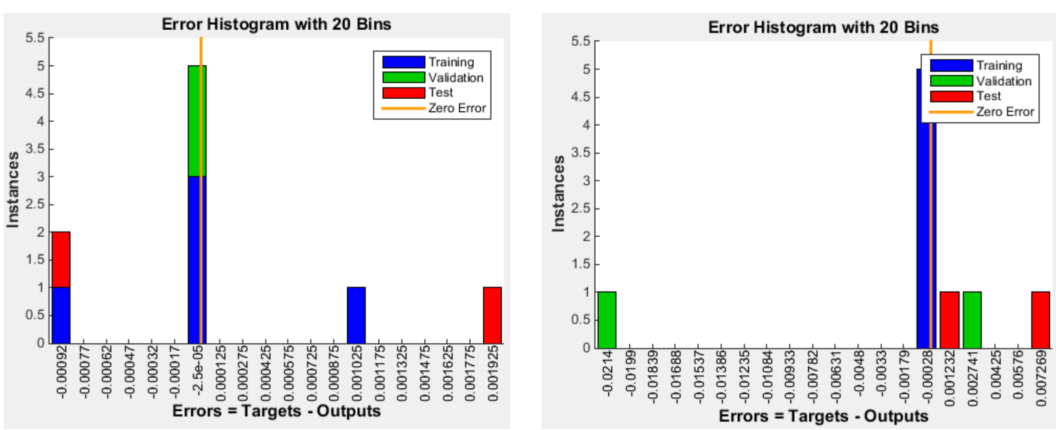


Figure 54: a) 1:1000 (30 cm) and b) 1:500 (30cm)

Graph shown above show the range value of error that occur from running the data sample for each parameter.

4.3.3.10 Error Graph (Acoustic Doppler Velocimeter (ADV))-with Module

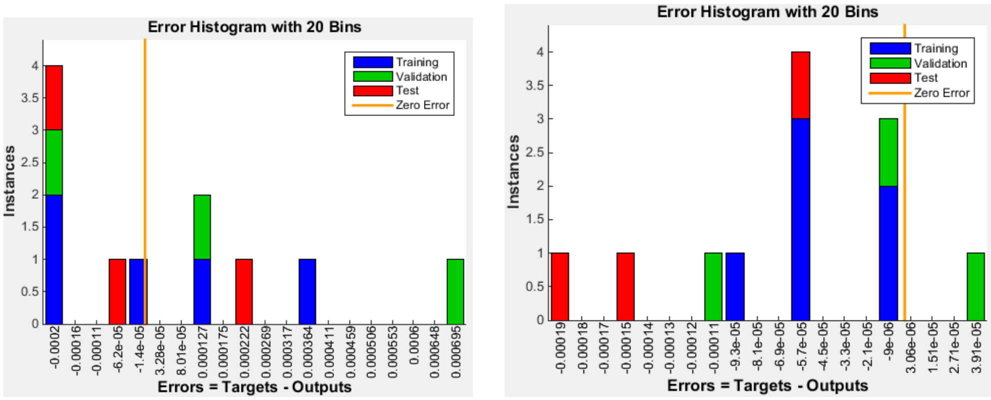


Figure 55: a) 1:1000 (10 cm) and b) 1:500 (10cm)

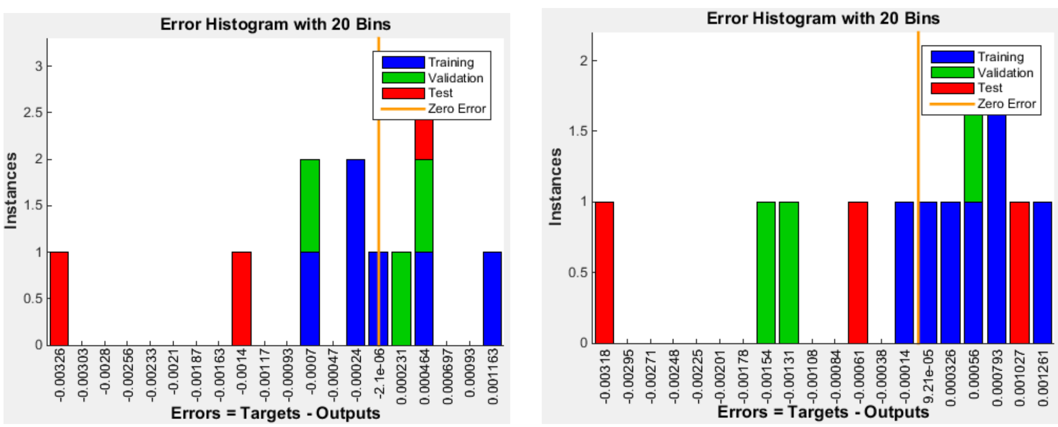


Figure 56: a) 1:1000 (20 cm) and b) 1:500 (20cm)

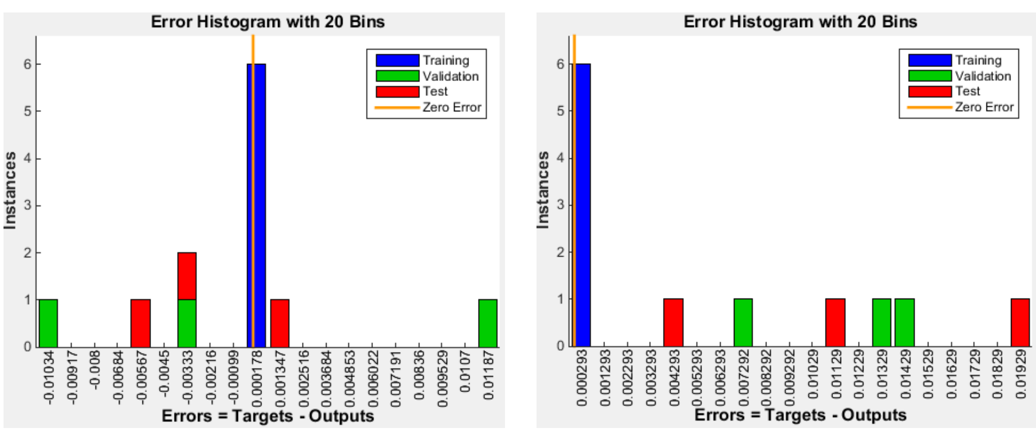


Figure 57: a) 1:1000 (30 cm) and b) 1:500 (30cm)

Graph shown above show the range value of error that occur from running the data sample for each parameter.

4.3.3.10 Error Graph (Acoustic Doppler Velocimeter (ADV))-without Module

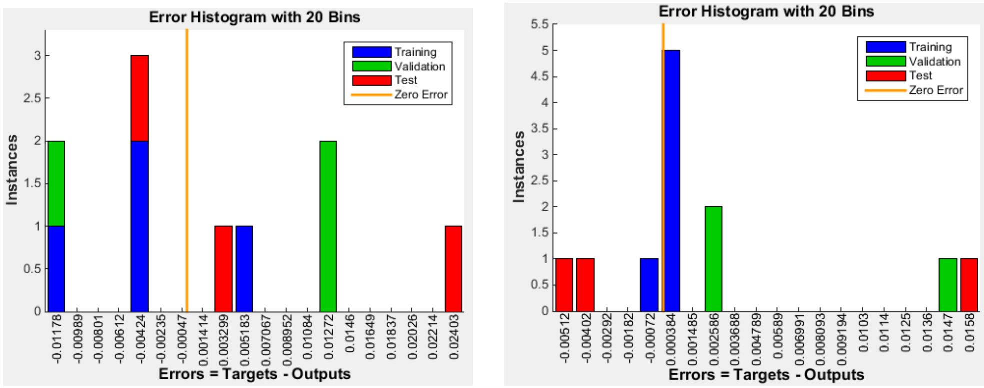


Figure 58: a) 1:1000 (GPO) and b) 1:500 (GPO)

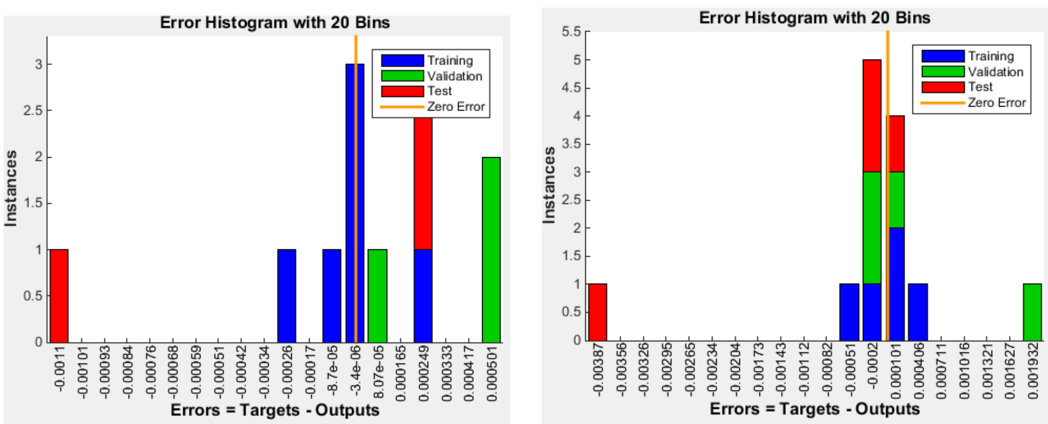


Figure 59: a) 1:1000 (GFO) and b) 1:500 (GFO)

Graph shown above show the range value of error that occur from running the data sample for each parameter.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

The application of module in channel system will help to manage the surface runoff of storm water at the downstream and reduce the risk of flood to occur in urban area. The performances of the modular channel in terms of flow resistance is able to be achieved at the end of this research.The flow resistance were affected by the module by decreasing the water level at downstream and also increasing the velocity and flow rate at downstream. The higher the value of Manning's roughness coefficient, n the lower the value of flow rate, Q will be as it is inversely proportional.

In this research, the highest Manning's n value of flume without module for Gate Partial Opening (GPO) is 0.244 (1:1000) and 0.234 (1:500) while Gate Fully Opening (GFO) is 0.028 (1:1000) and 0.021 (1:500). Highest Manning's n value of flume with module is 0.186 (1:1000) and 0.269 (1:500). As stated above, n (=0.269) is higher than n (=0.234) that validate the modular channel function to increase flow resistance. Steeper slope will have higher Manning's n value than less steeper slope and some of the result is not accurate due to some error while obtaining the data.More accurate roughness and discharge values can be obtained in the future by increasing the number of sample and relying on this relationship.

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